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Impact of face covering on social cognition and interaction

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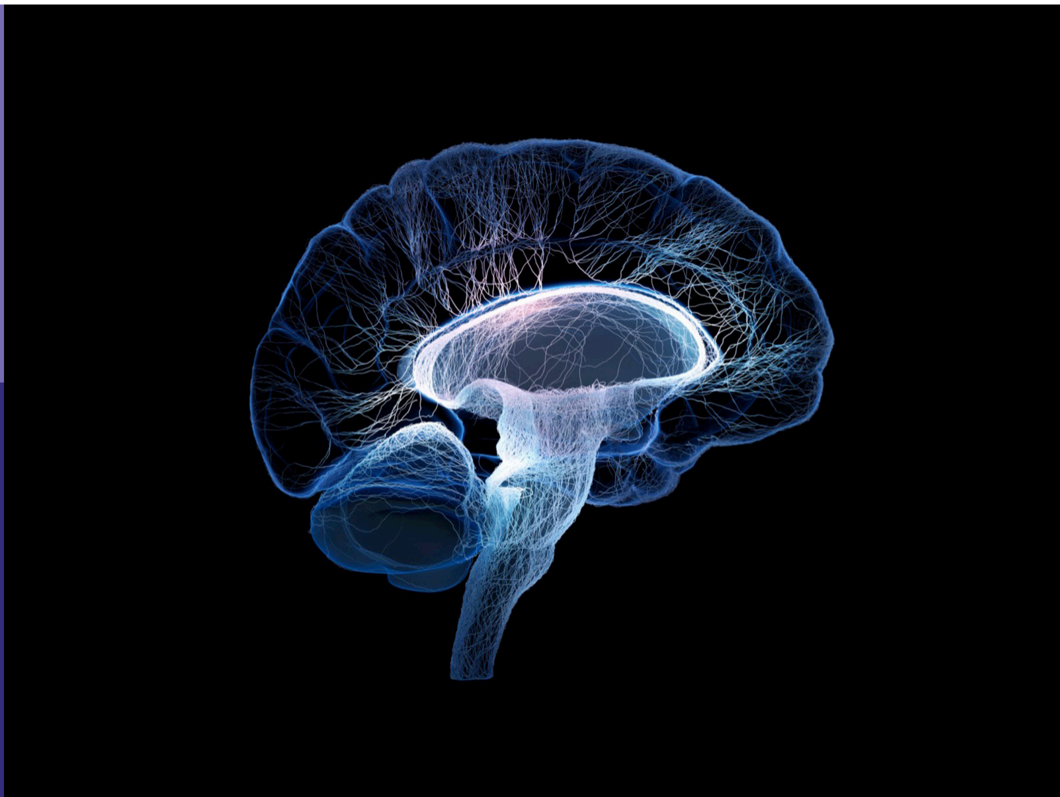

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Impact of face covering on social cognition and interaction

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Editorial: Impact of face covering on social cognition and interaction

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Editorial on the Research Topic
Impact of face covering on social cognition and interaction

Facemasks within and beyond the pandemic

Facemasks have become a familiar item due to the COVID-19 pandemic, but there is a multitude of further face coverings, with which we are confronted day-to-day and which impact our social cognition and interaction, for instance, scarves, headscarves, or bandanas. Such items might be used as protection, symbols of religious faith, or due to a mere fashion aspect, but all of them cover parts of a face, evidently reducing the overall amount of information we can gather. As coverings can be used as symbolic items, they can be psychologically charged, leading not only to a possible loss of information and shifts of attention but also to a potential adding of associations, perceptual biases, and prejudices.

In this Research Topic (https://www.frontiersin.org/research-topics/29292/impact-of-face-covering-on-social-cognition-and-interaction), 18 articles with 77 authors circling around this theme were edited by the international and interdisciplinary team of researchers and health professionals. The contributions came primarily from different parts of Western Europe and Canada. The Research Topic is urgently needed as, currently, we do not understand a full range of consequences elicited by a face covering that affect our mental processes, including perception, emotions, social cognition, and communication. While it seems that face coverings consistently impair the confident reading of facial expressions, recognition of identities, and the ability to understand speech from visual inputs, it is less understood how face coverings affect other aspects of social interaction (Figure 1). This will give answers to the questions of how they affect trustworthiness, perceiver's attitudes toward covered persons, or, for instance, how perceived gaze direction changes when looking at a covered face. The articles compiled for this Research Topic will provide a platform for joint interdisciplinary discussions and approaching the theme from different research perspectives and methodologies.

FIGURE 1
As shown by this Research Topic, facemasks affect emotion recognition and social interaction. Yet people easily differentiate between true and social (fake, dishonest) smiles even when covered by facemasks. Better no smile at all than a fake smile (Pavlova and Sokolov, 2022a). Some attempts to diminish the negative effects, in particular, in the healthcare system, require special rigorous experimenting. The image (courtesy of Jyo John Mulloor, a digital artist) is reproduced with his written permission.

Facial masking affects emotion recognition and social attribution

More traditional line of research is related to examination of the impact of facemasks on the recognition of emotions and social attribution (such as trustworthiness or attractiveness) by using static face photographs with superimposed on them masks. Overall, these studies nicely dovetail with the initial research outcome (Carbon, 2020; Cartaud et al., 2020; Biermann et al., 2021; Calbi et al., 2021; Gori et al., 2021; Grundmann et al., 2021; Kamatani et al., 2021; Marini et al., 2021, for comprehensive review, see Pavlova and Sokolov, 2022a). Yet only a handful of studies implements more ecologically valid dynamic faces (Leitner et al.; Aguillon-Hernandez et al.). Proverbio and Cerri report that although face masking reduces emotion recognition by about 30%, not all emotions are negatively affected. Face covering is most detrimental to sadness and disgust, while recognition of anger remains relatively intact. The authors speculate that facial masking polarizes non-verbal communication toward the happiness/anger dimension, while minimizing the impact of subtle emotions on empathic responses in the observer. Noteworthy, rather similar effects are demonstrated using dynamic faces: masks significantly impede the perception of disgust and sadness in videos of face expressions, whereas recognition of fear, neutral expressions, and social (fake, dishonest) smiling remains largely intact (Leitner et al.). Irrespective of facemasks, in dynamic faces, true Duchenne smiles are perceived as more honest than social smiles. In general, this is in line with earlier work with static faces. Even covered by masks true smiles are rated as happy and pleasant, in other words, *the glow of real smiles still shows* (Sheldon et al., 2021; see also Pavlova and Sokolov, 2022a). Unexpectedly, social fake smiles appear more honest in masked than in unmasked faces. Verroca et al. show that facemasks reduce the perceived intensity of facial expressions (except for extreme fear), and the ability to recognize subtle expressions, such as moderate fear and disgust. These detrimental effects, particularly for disgust (very often misinterpreted as anger), but also for happiness and sadness, do not seem to be reduced by habituation or learning. Indeed, Carbon et al. have demonstrated no improvement in the ability to recognize facial expressions after 1 year of surgical mask usage among the population. Face masking affects not only reading of face language, but also speech recognition. By using videos of dynamic faces, Aguillon-Hernandez et al. show that surgical masks impair the recognition of happiness and sadness (but not neutral expressions), as well as of spoken bilabial syllables. Mask covering appears not only to impair effective communication, but also to alter emotional transfer between people and social attribution processes. Leder et al. presented photographs of individuals in daily situations with and without masks, asking participants to evaluate their attractiveness, liking, and character. Persons wearing masks were perceived as more attractive and valuable by people with strong positive attitudes toward protective devices. In agreement with earlier reports (see review by Pavlova and Sokolov, 2022a), facemasks were found to impair the ability to evaluate people's trustworthiness and personal traits (Cannito et al.), on which economical transactions (e.g., risky choices) are commonly based. In summary, face covering alters many social processes.

Impact of face covering on social interaction

Studying interpersonal spatial adjustments, Geers and Coello find that social and peripersonal spaces are interconnected with a preference for shorter distances in females compared to males. Wearing a face mask induces shorter social distances primarily in persons with high aversion to risks and germs, which the authors interpret as an influence of the behavioral immune system on social interactions. Thomas et al. report that facemasks enhance significance of extraneous information such as head orientation and gaze direction, in particular, for emotions poorly recognized with a mask. Furthermore, facemasks make the eyes more noticeable, which leads to several perceptual biases. Lobmaier and Knoch show that mutual gaze is not recognized more accurately in masked faces, whereas Liu et al. report that facemasks induce a wider range of gaze angles associated with mutual gaze perception, increasing the feeling of "*being looked at*." This highlights social significance of a gaze potentially causing inappropriate social behavior. Villani et al. demonstrate that under conditions associated with an approaching behavior, wearing a mask forces people to jointly orient visual attention in the direction of a seen gaze. By using videos of moving faces, Rabadan et al. show that a facemask alters visual exploration of faces, with less time spent in its lower part, but preserves pupil reactivity to facial expressions. They conclude that although facemasks impair emotion recognition, implicit physiological responses to facial expressions remain unchanged. Overall, these studies reveal that facemask wearing may alter some aspects of perception of non-verbal social cues, in particular, those usually used to adjust interpersonal behavior in various social contexts.

Impact of facemasks is diminished by other social signals

For achieving efficient daily-life social interaction during the COVID-19 pandemic, we are forced to combine social signals from different sources such as the eyes (with a face hidden behind a mask) and bodies. Clarifying the issue of how facemasks affect face reading in real life, where we deal with dynamic faces and have access to additional social signals such as body language, warrants rigorous experimental work (Pavlova and Sokolov, 2022a). In real life, we usually cope with plentiful and often redundant social information that helps to prevent paying high costs for maladaptive social interaction, and, therefore, conceivably diminishes effects of masks. In accord with this, Ross and George report that the negative impact of masks on recognition of facial emotions (anger, happiness, fear, and sadness) becomes negligible for all emotions (except for happiness) when a whole body with a congruent static posture is visible. Nevertheless, with masks, confidence levels are lower for all emotions despite an additional body information. Moreover, Pavlova et al. show that in males, reading language of the eyes (when the overall amount of available information is rather comparable with that in faces covered by masks) is knotted with reading of dynamic point-light faces, while in females, inferring emotions from dynamic point-light bodies and faces are firmly linked. Amazingly, in males only, accuracy of the eyes, face, and body reading was found to be negatively tied with autistic traits. This outcome further underscores gender-specific modes in reading covered faces as well as reading language of the eyes (Pavlova and Sokolov, 2022b). On the same wavelength, McCrackin and Ristic demonstrate that the negative impact of masks on judgment of emotional valence and intensity in static faces (depicting happiness and sadness) is lessened by the availability of a larger emotional context, for instance, prior presentation of written statements such as "*Her pet cat was found yesterday afternoon*."

Face masks in mental disorders and during psychotherapy

Reading covered faces may be particularly challenging for individuals with neuropsychiatric conditions characterized by aberrant non-verbal social cognition already in the pre-pandemic period (Pavlova and Sokolov, 2022a). In one of the pioneering studies conducted by Escelsior et al., among patients with major depressive disorder (MDD), schizophrenia (SZ), bipolar disorder (BD), and typically developing individuals, patients with MDD and SZ were found to experience most difficulties in identifying subtle expressions of happiness. Erschens et al. present the outcome of a survey in patients ($N = 66$) and healthcare professionals ($N = 33$): (i) whereas patients report the impact of masks on individual psychotherapy and relationships with psychotherapists to be low, facemasks have greater subjectively estimated effects on the interaction group therapy; and (ii) negative effects of facemasks on therapeutic treatment are reported more frequently by professionals.

Limitations and further directions

In a nutshell, the work presented in this Research Topic nicely dovetails with and enriches the outcome of initial studies. Alongside a more traditional and widespread line of research on face covering effects on emotion recognition in static faces and social interaction, there are also ground-breaking studies on dynamic faces as well as the influence of context and other social signals (such as bodies) and ties between them. However, there is still a lack of developmental (including healthy aging), cross-cultural and brain imaging work, in particular, in psychiatric and neurological populations. The most research remains online with its well-known advantages (in particular, during the pandemic), but also rather serious limitations. As reported by the first comprehensive analysis on the topic (Pavlova and Sokolov, 2022a), online studies may create a sampling bias (e.g., study samples are usually heavily predominated by young women) precluding a proper generalization of findings. In addition, standardization of visual input is limited in some studies: faces with different emotions substantially differ not only in facial information *per se*, but also in head tilts and face angles. Other boundaries already mentioned earlier currently remain as well, namely: (i) displayed expressions (by performers asked to demonstrate) instead of natural *truly felt* emotions; and (ii) basic emotions instead of complex mental states. The most promising asset to future research and intervention appears to be an assessment of facemasks impact on social interaction and cognition in *daily-life* situations.

Author contributions

MAP conceptualized the structure of the manuscript, elaborated suggestions made by C-CC, YC, AAS, and AMP, placed together all portions, and drafted the manuscript. All authors substantially contributed to the article by writing manuscript sections and editing the paper, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: an experimental study. *PLoS ONE* 16, e0251393. doi: 10.1371/journal.pone.0251393

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: an online study on face covering. *Sci. Rep*. 11, 2601. doi: 10.1038/s41598-021-81780-w

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol*. 11, 566886. doi: 10.3389/fpsyg.2020.566886

Cartaud, A., Quesque, F., and Coello, Y. (2020). Wearing a face mask against Covid-19 results in a reduction of social distancing. *PLoS ONE* 15, e0243023. doi: 10.1371/journal.pone.0243023

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking emotions: face masks impair how we read emotions. *Front. Psychol*. 12, 669432. doi: 10.3389/fpsyg.2021.669432

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS ONE* 16, e0249792. doi: 10.1371/journal.pone.0249792

Kamatani, M., Ito, M., Miyazaki, Y., and Kawahara, J. I. (2021). Effects of masks worn to protect against COVID-19 on the perception of facial attractiveness. *Iperception* 12, 1–14. doi: 10.1177/20416695211027920

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep*. 11, 5577. doi: 10.1038/s41598-021-84806-5

Pavlova, M. A., and Sokolov, A. A. (2022a). Reading covered faces. *Cereb. Cortex* 32, 249–265. doi: 10.1093/cercor/bhab311

Pavlova, M. A., and Sokolov, A. A. (2022b). Reading language of the eyes. *Neurosci. Biobehav. Rev*. 140, 104755. doi: 10.1016/j.neubiorev.2022.104755

Sheldon, K. M., Goffredi, R., Corcoran, M. (2021). The glow still shows: effects of facial masking on perceptions of Duchenne versus social smiles. *Perception*. 50:720–727. doi: 10.1177/03010066211027052

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Reading Emotions in Faces With and Without Masks Is Relatively Independent of Extended Exposure and Individual Difference Variables

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The ability to read emotions in faces helps humans efficiently assess social situations. We tested how this ability is affected by aspects of familiarization with face masks and personality, with a focus on emotional intelligence (measured with an ability test, the MSCEIT, and a self-report scale, the SREIS). To address aspects of the current pandemic situation, we used photos of not only faces *per se* but also of faces that were partially covered with face masks. The sample ($N = 49$), the size of which was determined by an *a priori* power test, was recruited in Germany and consisted of healthy individuals of different ages [$M = 24.8$ (18–64) years]. Participants assessed the emotional expressions displayed by six different faces determined by a 2 (sex) × 3 (age group: young, medium, and old) design. Each person was presented with six different emotional displays (angry, disgusted, fearful, happy, neutral, and sad) with or without a face mask. Accuracy and confidence were lower with masks—in particular for the emotion disgust (very often misinterpreted as anger) but also for happiness, anger, and sadness. When comparing the present data collected in July 2021 with data from a different sample collected in May 2020, when people first started to familiarize themselves with face masks in Western countries during the first wave of the COVID-19 pandemic, we did not detect an improvement in performance. There were no effects of participants' emotional intelligence, sex, or age regarding their accuracy in assessing emotional states in faces for unmasked or masked faces.

Keywords: emotion perception, face mask, personality, emotional intelligence, accuracy, face perception, COVID-19 pandemic, cover

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SIGNIFICANCE STATEMENT

The present study validates previous findings that the reading of emotions in faces is impaired when faces are partially covered with a mask (the emotional state of disgust was especially difficult to read)—even 1 year after wearing face masks became common. Although there was a wide range of performance levels, emotional intelligence, assessed with a performance test or with self-reports, did not affect the specific confusion of perceived emotions for faces with or without masks. During a pandemic, it seems necessary to provide and use additional information so that interaction partners' emotions can be assessed accurately.

INTRODUCTION

A face probably conveys hundreds of dimensions of information, which people can typically read quickly and with little cognitive effort. Besides the socially important dimension of identification, even if we take only a single glance at a person's face before executing any deeper exploration (Carbon, 2011), their face allows us to assess several other dimensions that are relevant for the raw assessment of a social situation, for example, attractiveness (Carbon et al., 2018), bodyweight (Schneider et al., 2012), and trustworthiness (Willis and Todorov, 2006). The perception of emotions is an additional highly complex ability (Herpertz et al., 2016) as not only basic emotions but even highly differentiated mental states can be inferred from faces, especially on the basis of the region around the eyes (Schmidtmann et al., 2020). All of these pieces of information are assumed to be processed in a rather parallel and highly efficient way (Bruce and Young, 1986), a theoretical claim that indeed has found support from brain research (Haxby et al., 2001). Emotion perception can be considered an aspect of emotional intelligence and is an ability that is related to the wellbeing of both actors and partners (Koydemir and Schütz, 2012) and can be increased through training (Gessler et al., 2021). Such a highly optimized and efficient way of processing facial information can easily be impaired.

During the COVID-19 pandemic, a substantial change in the opportunity to thoroughly perceive facial expressions occurred when the use of face masks became obligatory, which was the case in many countries during the first wave of COVID-19 in May 2020. This global change in the opportunity to perceive facial expressions provides an interesting setting for testing whether the ability to read faces can adapt to such an environmental change. The present study was aimed at analyzing indications of improvements in face reading after having been exposed to partially covered faces for 1 year. For interested readers, we would like to refer to an overview of all kinds of effects documented so far for the use of masks (Pavlova and Sokolov, 2021). However, in the following study, we focus on the effects on emotion reading. We were interested in not only such a possible adaptation but also in variables that could potentially affect the ability to read emotions in faces, foremost the personality variable of *emotional intelligence* (Mayer and Salovey, 1997).

We know from research during the COVID-19 pandemic that adults (Carbon, 2020) as well as (9–11 year old) children (Carbon and Serrano, 2021) are less effective in reading emotions when face masks cover a target's mouth and nose region. These general findings were replicated several times in 2020 (e.g., Gori et al., 2021; Grundmann et al., 2021) and 2021 (Ramachandra and Longacre, 2022). Specific emotions are especially difficult to discern when face masks are worn. This is the case for all emotions that are strongly expressed by movements in the mouth area (e.g., disgust, anger, sadness, and happiness; see Bombari et al., 2013). For these emotions, recognition is heavily impaired when a face mask is worn (Carbon, 2020). Pre-COVID-19 studies had already shown this general finding, although the results had been inconsistent (see Bassili, 1979; Fischer et al., 2012; Kret and de Gelder, 2012), which calls for further investigation into the specific impairments of face covers for certain emotions.

Emotional intelligence (EI) plays a significant role in the decoding of facial expressions. More precisely, EI is the ability to perceive and regulate emotions in oneself and in others (Mayer and Salovey, 1997). Individuals with better emotion perception skills are especially sensitive to changes in facial expressions and thereby better able to recognize emotions in others (Karle et al., 2018). In their updated Four-Branch Model of Emotional Intelligence, Mayer et al. (2008b) not only make the assumption that individuals high in EI are more adept at recognizing verbal and non-verbal information in others, such as facial or vocal cues, but also differentiate reasoning skills for each of the four branches which range from basic to more complex cognitive processes. According to this model, high EI individuals possess enhanced cognitive abilities that allow them to recognize emotions even under difficult conditions, such as integrating contextual and cultural aspects when decoding emotional expressions. Thus, especially when face masks cover parts of the face, individuals with high emotional intelligence should be better at identifying emotions in others and more confident in their judgments.

Throughout life, individuals continue to develop their emotional intelligence, which includes the ability to perceive emotions (Mayer et al., 2008a), and previous studies have shown that emotional intelligence can be improved by traditional face-to-face training (e.g., Hodzic et al., 2018; Gessler et al., 2021) as well as online training (Köppe et al., 2019), thus highlighting the importance of experience and practice in developing and increasing emotion perception skills. With regard to the current context of a pandemic, individuals who regularly interact with others who wear face masks should be especially skilled at detecting emotions despite the use of face masks. In addition, it is reasonable to assume that individuals have improved their emotion perception skills after having been confronted with partially covered faces for a while. Thus, the respective abilities should be better now than they were at the onset of the COVID-19 pandemic.

When assessing the impact of emotional intelligence, it is important to differentiate between performance-based and self-report measures as performance-based measures are more strongly related to cognitive ability, whereas self-reports are more closely linked to other personality traits (Mayer et al., 2008b; Joseph and Newman, 2010). As a result, studies have revealed only weak correlations between performance-based and self-report measures (e.g., Brackett et al., 2006). For this reason, we employed both performance-based and self-report measures in the present study.

Numerous studies have indicated that individuals' emotion perception also depends on their attitudes, beliefs, and stereotypes regarding other people. Individuals who did not adhere to wearing face masks in everyday life exhibited more negative attitudes toward face masks (Taylor and Asmundson, 2021) and in the context of the COVID-19 pandemic, individuals who object to the COVID-19 restrictions appear to be separating themselves from the "mainstream" and their previous in-group. As a consequence, individuals who do not wear face masks should be worse at detecting emotions in masked faces (i.e., out-group members).

Last but not least, we were also interested in potential gender differences in processing facial emotions—a topic that has largely been neglected but has piqued interest in recent years, probably influenced by a meta-analysis on this topic in 2013 (Herlitz and Lovén, 2013). The authors of this meta-analysis showed that women had better performance in facial recognition and memories for faces than men (Herlitz and Lovén, 2013) and suspected that this advantage was due to more efficient configural and holistic processing, which also reflects an expertise-based mode of processing (Carbon and Leder, 2005; Rhodes et al., 2006) when processing facial information (e.g., age, Hole and George, 2011). However, in a recent study with a large sample of 343 participants employing the Cambridge Face Memory Test (CFMT; Duchaine and Nakayama, 2006) and the Cambridge Face Perception Test (CFPT; Duchaine et al., 2007), the holistic processing hypothesis was not supported (Østergaard Knudsen et al., 2021). Still, specifically for emotion recognition, it has been shown that women regularly outperform men, for instance, in the acoustic domain (e.g., for the recognition of vocal emotions; Mishra et al., 2019) or the visual domain [e.g., for the recognition of facial emotions (Wingenbach et al., 2018)].

On the basis of these considerations, we tested the following hypotheses, which were previously documented in our preregistration available on the Open Science Framework (OSF), retrievable *via*:[1]

- (H1) Emotion recognition will be better and participants' confidence in their judgments higher for faces without masks than for faces with masks.
- (H2) Participants' EI (both performance-based and self-reported) will be positively related to their ability to recognize emotions in faces and to their confidence in doing so.
- (H3) Participants' emotion recognition will be better and confidence will be higher than emotion recognition in a different but comparable sample measured 1 year ago.
- (H4) Familiarity with face masks will be positively related to emotion recognition and confidence.
- (H5) Positive attitudes toward face masks will be positively related to emotion recognition and confidence.
- (H6) For masked faces, emotion recognition will be worse for emotions in which the mouth area is important than in other emotions.
- (H7) Women will show better emotion recognition and higher confidence than men.
- (H8) Younger participants will show better emotion recognition and higher confidence than older adults.

[1]https://osf.io/c8zmn/

EXPERIMENTAL STUDY

The major aims of the present study were to gain knowledge about whether the ability to process facial emotions is adaptive and can be affected by presentation (masks vs. no masks), time (during the COVID-19 pandemic), and participants' sex and age. Further, we aimed to test whether performance in the processing of facial emotions can be affected by participants' emotional intelligence (EI) or participants' attitude toward face masks.

MATERIALS AND METHODS

Participants

Calculation of the Sample Size

We calculated the required sample size N using a test model that included EI as a fixed factor (Model 2) compared with a baseline model without EI (Model 1). As we followed a test strategy based on linear mixed models (LMMs), we calculated the test power a priori using the R package simr (Green and MacLeod, 2016). To compare the two models, we set the intercept to 60% (the dependent variable was the performance level, which could range from 0 to 100%, so 60% indicates a medium-high performance level given a six Alternative Forced Choice (AFC) design with a 16.7% base rate). The slopes of the fixed effects of emotions were set to −2, +5, +5, +5, and + 10 for the different emotional states (disgust, anger, neutral, happiness, and fear, respectively) compared with the emotional state of sadness, based on typical findings for these emotions (e.g., Carbon, 2020). For Model 2, we set the slope of the fixed effect of EI to +2, the random intercept variance was set to 10, and the residual standard deviation was set to 20. With 1,000 simulations, we obtained a test power of 90% [95% CI (89.16, 92.79)] with a sample size of $N = 46$.

We recruited the N we needed plus 5 additional individuals (initially we planned to oversample up to $N = 54$) given that invalid data are typically expected from about 1/5 of participants, but a preliminary inspection of the data (looking for potential indicators of data that should be excluded as documented in the preregistration, i.e., very low performance and many missing data points) indicated a much smaller amount of invalid data; only two participants were excluded due to the preregistered outlier criterion of having correctly identified the emotional states of faces without face masks in less than 50% of the cases.

Sample

The final sample consisted of 49 participants [$M_{age} = 24.8$ years (18–64 years), $N_{female} = 39$], yielding a *post-hoc* power of 92.10% [95% CI (90.25, 93.70)]. People had been recruited by different online advertisements; they were not directly incentivized but had the option to participate in a lottery with prizes ranging from 10 to 100 Euros (5 × 10 Euros, 1 × 50 Euros, and 1 × 100 Euros).

Material

The baseline face stimuli without masks were obtained from the MPI FACES database (Ebner et al., 2010) on the basis of a study-specific contract effective 19 April 2021. We used frontal photos of six Caucasians (three female and three male) who belonged to three different face age groups [*young*, *medium* = middle-aged, *elderly* with average perceived ages of 25.5, 41.5, and 67.0 years, respectively, as shown in a previous study by Ebner et al. (2010)] as baseline images to which we subsequently applied face masks with a graphics editor. Each person showed the emotional states *anger, disgust, fear, happiness,* and *sadness,* and one *neutral expression*. Each *face sex* × *face age group* cell was represented by one specific person. We doubled all of the 2 [face sex] × 3 [face age groups] × 6 [emotional states] = 36 baseline pictures to apply a typical face mask used during the COVID-19 pandemic (a so-called "community mask" colored beige). For each manipulated picture, the mask was individually adapted to fit the different faces perfectly; we added realistic shadow effects to further increase the realism of the pictures with face masks (**Figure 1**).

Overall, the material consisted of 2 [no mask vs. mask] × 36 = 72 facial stimuli, half of the original material originally used by Carbon (2020). Specifically, we used only one of the two face age group representatives per sex from the original study. This was done to reduce the total duration of the present study, which was substantially extended by adding the personality variables.

Apparatus

Study Platform

As the study platform, we used the online tool SoSci Survey,[2] which is freely available for non-profit-oriented scientific projects.

[2]https://www.soscisurvey.de/

Measures

Ability-Based Emotional Intelligence

We used the faces and images subtasks from the German version of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Steinmayr et al., 2011) to assess ability-based emotion perception. Participants used a 5-point scale to indicate the degree to which each of five emotions was expressed in a photograph (faces subtask) or pictures of landscapes and abstract patterns (images subtask). In line with previous research, internal consistency analyses revealed a Cronbach's alpha of $\alpha = 0.683$ for the faces subtask, $\alpha = 0.833$ for the images subtask, and $\alpha = 0.857$ for the emotion perception scale in this study.

Self-Reported Emotional Intelligence

The Perceiving Emotion subscale from the German version of the Self-Rated Emotional Intelligence Questionnaire (SREIS, see Vöhringer et al., 2020) was employed to assess emotion perception skills *via* self-report. Participants rated their emotion perception skills on a 5-point scale ranging from 1 (*very inaccurate*) to 5 (*very accurate*). Again, internal consistency analyses were computed, and Cronbach's alpha for the SREIS was $\alpha = 0.520$.

Attitudes Toward Face Masks

Participants' overall attitude toward face masks was measured with a single item "What is your personal opinion toward the mandatory use of masks?" with the response options: "I do not consider the mandatory use of masks a problem," "To me the mandatory use of masks is annoying but bearable," and "I consider the mandatory use of masks unreasonable and burdensome." Further, we employed the 12-item scale developed

FIGURE 1 | The figure illustrates the six emotional variations (anger, disgust, fear, happiness, neutral, and sadness) of one person without **(A)** and with **(B)** a face mask. This specific person was not part of our experimental material but is presented here for illustrative purposes. The authors would like to thank the Max Planck Institute for providing the baseline stimuli (without masks), which came from the MPI FACES database (Ebner et al., 2010).

by Taylor and Asmundson (2021) with answers that were rated on a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*) to allow for a more fine-grained analysis of face mask attitudes. Internal consistency was $\alpha = 0.906$ for the 12-item scale.

Face Mask Use

Participants indicated their individual face mask use (FamiliarityOwnMask) by rating the item "On average, how many hours a day do you wear a face mask?" on a 10-point scale ranging from 1 (*max. 30 min*) to 10 (*more than 8 h*). In addition, we asked participants to rate their daily duration of interpersonal contact with face masks (FamiliarityOthersMasks) by answering the item "How many hours per day are you in face-to-face contact with others who wear a face mask?" on a 10-point scale ranging from 1 (*max. 30 min*) to 10 (*more than 8 h*).

Procedure

We conducted the study between 13 July 2021 (13:09 local time; CEST) and 19 July 2021 (11:52 local time; CEST) during the end of the third wave of the COVID-19 pandemic in Germany. Each participant gave written consent to participate in the study; data were collected anonymously. We first asked general demographic questions about participants' age and sex. Then, the experimental part began. We fully randomized the order of the stimuli for each participant. The participant's task was to assess the depicted person's emotional state using a six Alternate Forced Choice (AFC) task where all six of the possible emotional states were shown as written labels (in German: *anger*, *disgust*, *fear*, *happiness*, *neutral*, and *sadness*) along with a confidence scale. So by clicking on one scale point of the respective confidence scale the participants indicated the perceived emotional state as well as the confidence with just one click. The confidence scale was used to assess the participant's confidence in their recognition of the respective emotion expression on a 7-point scale ranging from 1 (*not confident at all*) to 7 (*very confident*). We did not set a time limit for the assessment but asked participants to respond spontaneously. The next trial started after the participant pushed a response key, initiated by a short, intermediate pause with a blank screen presented for half a second. After the experimental part, we administered all questionnaires and single questions. Participants took 27.5 min on average to successfully complete the whole study. We obtained ethical approval for the general psychophysical study procedure from the local ethics committee of the University of Bamberg (Ethikrat).

RESULTS

We employed R 4.1.2 (R Core Team, 2021) to process and analyze the empirical data, mainly by using linear mixed models (LMM) in the package *lme4* (Bates et al., 2015). The preregistered study as well as the (anonymized) data can be found on the OSF.[3]

[3]https://osf.io/rfmv7

Performance was calculated as a percentage of correct data, confidence was converted to percentage ratings such that the minimum confidence rating of 1 corresponded to 0%, and the maximum confidence rating of 7 corresponded to 100% confidence. We obtained a mean performance level for the baseline condition of faces without masks of $M = 89.1\%$, which is remarkable given that a chance rating for a six AFC is 16.7%. For the faces with masks, the performance level dropped to 73.3%, which was still much higher than chance. The drop in performance was evident for four of the six emotional states from the visual inspection of **Figure 2**—for anger, disgust, happiness, and sadness.

We inspected the drop in performance when faces wearing masks had to be inspected by observing the confusion matrices for expressed versus assessed emotions. As **Figure 3** indicates, there was confusion of emotions even when the entire face (without a mask) was shown. This was especially true for sadness, which was correctly identified in 70.4% of the cases and misinterpreted as disgust in about 25% of the cases. Recognition of the other emotions was quite good with correctness levels above 88.4% (for anger) or higher (e.g., 99.7% for happiness).

When faces were shown with masks, participants were more confused about which emotion was displayed. This was particularly the case for disgust, which participants very often misinterpreted as anger (32.7%). Sadness was diffusely assessed, with no clear misinterpretation for a single emotion, but with a broad spectrum of interpretations ranging across fear, neutral, disgust, or anger. The exceptions to the rule were neutral and fear, which were not negatively affected by adding a face mask.

We also analyzed the data on participants' confidence in choosing the respective emotional state. As **Figure 4** indicates, participants showed numerically lower confidence when assessing masked faces. With five out of six emotions, we found statistically significant drops in confidence: for anger, disgust, happiness, neutral, and sadness.

We tested the effect of wearing masks on performance and confidence with two separate linear mixed models (LMMs). As the null model (Model 0), we used a simple one containing the participants and baseline stimuli as random intercepts and *facial emotion* as a fixed effect. For Model 1, we added *face mask* (face with a mask vs. without a mask) as a fixed factor. The coefficient of determination for each model was calculated *via* a likelihood-ratio test utilizing the R package *MuMIn* (Barton, 2019).

For both dependent variables (i.e., performance and confidence), we obtained significant effects of *face mask*, $ps < 0.0001$, with a drop in performance of 15.8% and a drop in confidence of 11.9%. This result supported H1. For details, see **Table 1**.

We also tested H2, in which we focused on the relationship between participants' ability-based or self-reported emotional intelligence (EI) and their performance and confidence in assessing emotional expressions in faces. We used an LMM approach with Model 2 including EI (ability-based emotional intelligence) and SREIS (self-reported emotional intelligence) as fixed factors compared with Model 1 where these EI-related scores were not included. We also analyzed the correlation between EI and SREIS, which turned out to be nonsignificant,

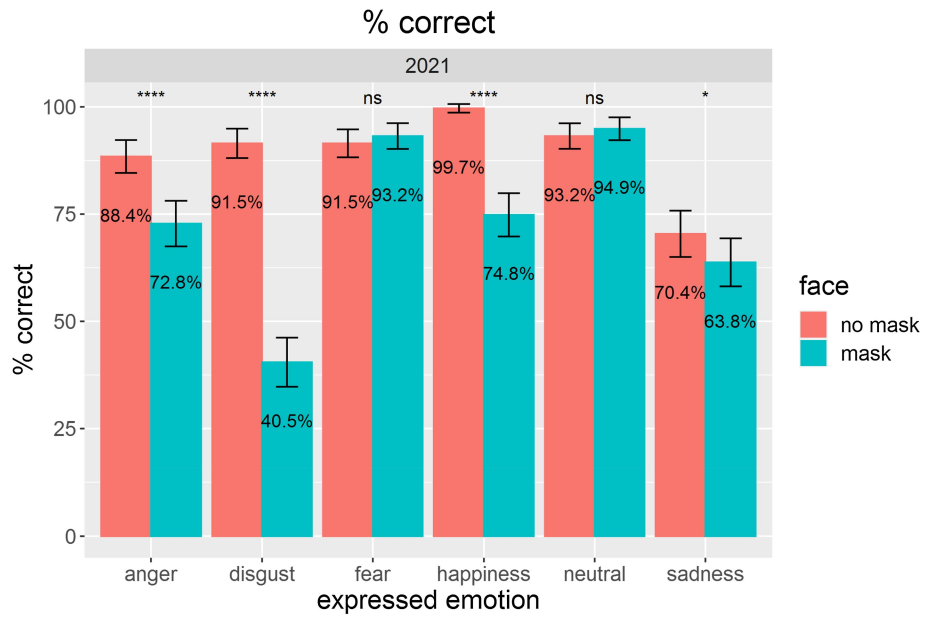

FIGURE 2 | The figure demonstrates mean performance levels for assessments of emotional states for faces without masks (red) compared with faces with masks (blue). Error bars indicate 95% confidence intervals (CIs) according to Morey (2008). Pairwise comparisons of the presentation conditions were calculated *via* undirected paired t-tests. $^{*}p<0.05$. $^{****}p<0.0001$. Nonsignificant results are marked with ns.

$r=0.01$, $p=0.93$, *ns*. For both dependent variables, we did not explain more variance by including EI-related scores (see **Table 1**). Thus, H2was not supported.

We also tested H3, which proposed that people in the present sample from 2021 would have higher scores (higher performance and higher confidence, respectively) than the original sample tested with the same experimental procedure in 2020. Note: As the 2020 study used twice as many stimuli, we analyzed only the material used in both studies. Again, we followed an LMM approach, this time with the merged data set, which comprised the 2020 sample consisting of 41 participants and the 2021 sample consisting of 49 participants, yielding a total of $N=90$ participants. This time, as the null model, we used Model A0, which in fact reflected the previous Model 0 but was fed by the overall data set comprising the 2020 and 2021 data. Model A1, which included *Study* (2021 vs. 2020) as a fixed factor, was not able to explain additional variance for the performance or the confidence data. Thus, H3 was not supported, $ps>0.7638$.

Regarding H4, we tested whether greater familiarity with face masks would lead to better performance or confidence, respectively, in assessing facial emotions. This was done with Model 3 to which we added *familiarity*. We measured the familiarity with face masks in two ways: The first item asked about familiarity with face masks in terms of a person's own use of face masks per day (*FamiliarityOwnMask*), whereas the second item asked about familiarity with face masks in terms of perceiving other people with face masks (*FamiliarityOthersMasks*). As the two aspects capture different perspectives of the aspect of familiarity, we decided to add them to Model 3 as two different fixed factors (Models 3a and 3b, respectively), which we tested against Model 1. We revealed that *FamiliarityOthersMasks* was significantly related to higher performance as well as higher confidence in the assessment of facial emotions, whereas *FamiliarityOwnMask* failed to reach significance with the given power.

We tested H5, which were about the relationships between people's attitudes toward face masks and the dependent variables performance and confidence, respectively, in assessing facial emotions. Again, we tested this against Model 1 with an LMM. Model 4 which included the additional fixed factor *attitudeMasks* did not explain more variance than Model 1, so H5 was rejected.

Regarding H6, we analyzed the selective decrease in performance in assessing certain facial emotions when faces were shown with masks, again utilizing an LMM approach. We did not use *face mask* as a fixed factor as in Model 1 but as an interactive effect with *exprEmo* and tested this Model 5 against Model 1. As expected, we found a stronger effect of face masks on performance in identifying facial emotions for which the mouth area was indicative (anger, disgust, happiness, and sadness) versus nonindicative (fear). As shown in **Table 2**, we obtained a nonsignificant effect of the interaction between *face mask* and the emotion *fear*, probably because fear is mainly expressed by the eyes. By contrast, we obtained clearly reduced performances in detecting anger, disgust, happiness, and sadness when a mask covered the mouth region. The largest effect was observed for disgust.

H7 addressed effects of participants' sex on performance and confidence, respectively, of correctly assessing the emotional states depicted in faces. We tested both hypotheses with an

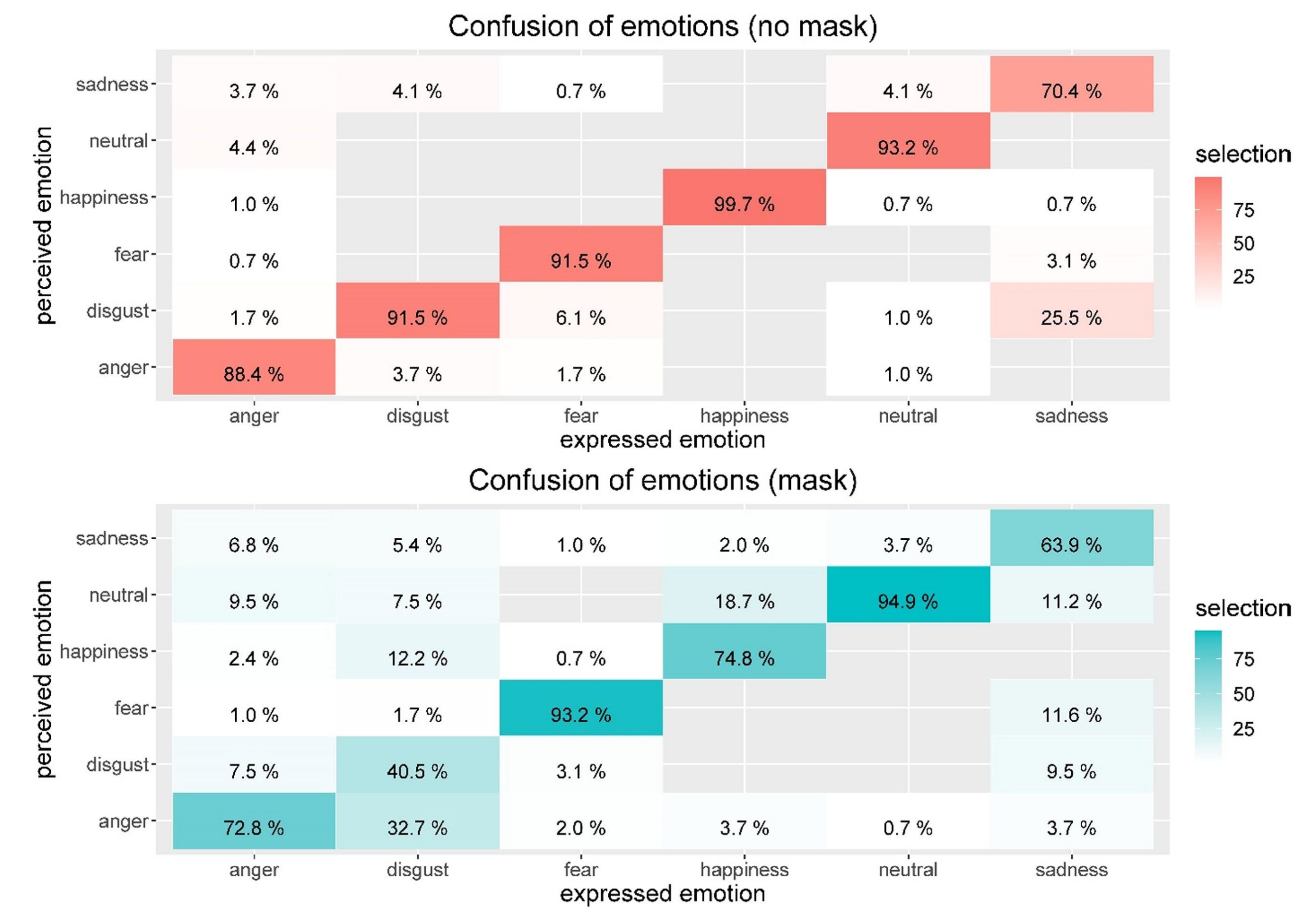

FIGURE 3 | This figure shows the confusion matrices for expressed versus perceived emotions for the original faces without face masks (top red) and faces with face masks (bottom blue). Mean performance levels in assessing the emotional states are given by percentage correctness rates (if >0.5%, otherwise data were suppressed for better readability of the matrices). The better the performance, the more saturated were the confusion matrix cells.

LMM by adding the fixed factor of participants' sex (Model 6) against Model 1. There was no significant effect of participants' sex for performance or for confidence, $ps > 0.5970$.

H8 tested effects of participants' age on performance and confidence. We tested both hypotheses with an LMM by adding the fixed factor of participants' age (Model 7) against Model 1. There was no significant effect of participants' age for performance or for confidence, $ps > 0.1121$.

DISCUSSION

During the different waves of the COVID-19 pandemic, face masks have consistently been used as simple, cheap, and easy-to-apply methods to effectively reduce the transmission of CoV-SARS2 (Howard et al., 2021). Having started with low acceptance in Western countries due to the lack of familiarity with its use in early 2020, the face mask became an ideogram of the pandemic, and with everyday experience, acceptance increased (Carbon, 2021).

In the present study, we tested how individual difference variables were related to the ability to assess emotions in faces with and without masks and whether exposure to masks has improved the ability to infer emotional states from the remaining facial area that is not covered by the mask. We know from the literature that such little facial information is sufficient for recognizing mental states, such as being confident, doubtful, upset, or uneasy (Schmidtmann et al., 2020). This is astonishing because, in typical everyday life situations, aside from a pandemic such as the COVID-19 pandemic, we are typically not exposed to such a reduction in facial information. When we conducted the present study at a time when people in Germany had been obliged to wear face masks in public for more than 1 ¼ years. This led us to assume that people would be familiar with face masks and skilled in reading emotions in partly covered faces. Despite this high level of familiarity with face masks, we observed reduced performance and confidence when people interpreted masked faces. Moreover, people were not better than people had been a year earlier (in April 2020, see also Mitze et al., 2020), but we have to

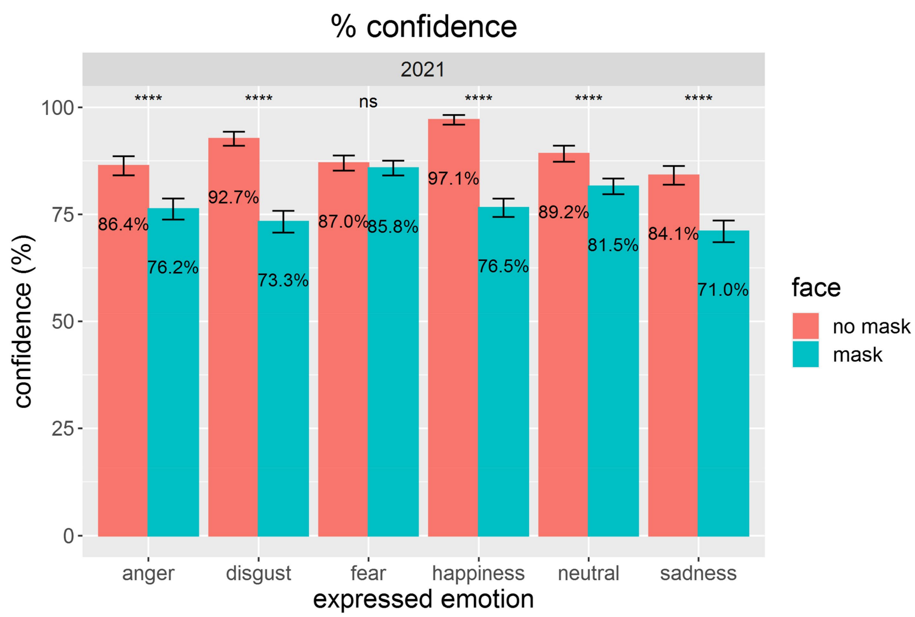

FIGURE 4 | This figure shows mean confidence levels for assessments of emotional states for faces without masks (red) compared with faces with masks (blue). Error bars indicate 95% CIs according to Morey (2008). Pairwise comparisons of the presentation conditions were calculated *via* paired t-tests. ****$p < 0.0001$. Nonsignificant results are marked with ns.

TABLE 1 | Comparison of different linear mixed effects models.

Dependent variable/ tested model	*df*	AIC	logLik	Cond.R^2	Against	$p(\chi^2)$
%correct						
#0: null	9	35,483	−17,732	0.128		
#1: + Mask	10	35,316	−17,648	0.168	#0	<0.0001
#2: + EI+SREIS	12	35,320	−17,648	0.168	#1	0.9081 *n.s.*
#3a: + FamiliarityOthers	11	30,243	−15,111		#1	<0.0001
#3b: + FamiliarityOwn	11	35,318	−17,648	0.168	#1	0.8360 *n.s.*
#4: + attitudeMasks	11	35,318	−17,648	0.168	#1	0.5975 *n.s.*
#5: + exprEmo:Mask	15	35,177	−17,527	0.224	#1	<0.0001
%confidence						
#0: null	9	37,253	−15,317	0.240		
#1: + Mask	10	30,246	−15,113	0.324	#0	<0.0001
#2: + EI+SREIS	12	30,324	−15,113	0.324	#1	0.9468 *n.s.*
#3a: + FamiliarityOthers	11	30,243	−15,111	0.324	#1	0.0325
#3a: + FamiliarityOwn	11	30,245	−15,111	0.324	#1	0.0838 *n.s.*
#4: + attitudeMasks	11	30,247	−15,113	0.324	#1	0.5115 *n.s.*

The table shows the results of linear mixed effects analysis of different models in comparison with less complex models, separated by the two tested dependent variables % correct (percentage of correct emotion classifications) and % confidence (for correct emotion classifications). FS, fixed slopes (fixed factors); RS, random slopes (random factors); df, degrees of freedom; R^2, conditional coefficient of determination, based on the likelihood-ratio test; and "against" indicates the model against which the current model was tested, $p(\chi^2)$ provides the probability of accepting a significant effect despite a nonexistent difference regarding the more complex model versus the model specified in the "against" column.

be very cautious about making this comparison because we did not test the same people nor did we use a matched sample. Still, the key parameters were very similar (German sample, mean age differed by only 1.8 years, comparable relative number of female to male participants).

Confusion between emotions in 2021 was similar to the effects documented 1 year earlier: whereas neutral faces and fear were usually well detected even when a face mask was present, anger was often misinterpreted as neutral, disgust, or sadness. Furthermore, sadness was often misinterpreted as neutral, fear, or disgust. Most dramatically, disgust was misinterpreted in nearly 1/3 of the cases and was identified as anger, happiness, or a neutral expression. Interestingly, happiness was often misinterpreted as a neutral expression. Such misinterpretations could be socially relevant in everyday life. For instance, if our counterpart signals affirmation or

TABLE 2 | Results of the linear mixed effects analysis for emotion recognition performance testing Model 5 against Model 1.

Predictors	Estimates	*p*	*df*
(Intercept)	93.20 ***	**<0.001**	3,514.00
Neutral	*Reference*		
Anger	−4.76	0.094	3,514.00
Disgust	−1.70	0.549	3,514.00
Fear	−1.70	0.549	3,514.00
Happiness	6.46 *	**0.023**	3,514.00
Sadness	−22.79 ***	**<0.001**	3,514.00
exprEmo_anger:Mask	−17.35 ***	**<0.001**	3,514.00
exprEmo_disgust:Mask	−52.72 ***	**<0.001**	3,514.00
exprEmo_fear:Mask	−0.00	1.000	3,514.00
exprEmo_happiness:Mask	−26.53 ***	**<0.001**	3,514.00
exprEmo_sadness:Mask	−8.40 *	**0.037**	3,514.00
No mask	*Reference*		
Mask	1.70	0.549	3,514.00
ICC		0.05	
$N_{\text{depictPers}}$		6	
N_{CaseID}		49	
Observations		3,529	
Marginal R^2/Conditional R^2		0.179/0.224	
AIC		3,5084.229	
Log-likelihood		−17,527.114	

*The table shows the statistics for all involved fixed effects in the linear mixed effects analysis for Model 5, regarding the tested dependent variable % correct (percentage of correct emotion classifications). Abbreviated notations for the terms were used to save space: exprEmo_XY = facial emotion, e.g., anger; Mask = face with face mask. Significant values of p are in bold. *p < 0.05 and ***p < 0.001.*

gratitude by expressing a happy face, we might not see this positive feedback and could misinterpret this social situation. Familiarity with masks was not a relevant factor regarding the ability to read faces either: Only when people were very often exposed to masked faces was their confidence slightly higher.

When analyzing the specific drops in performance or confidence regarding the recognition of emotions in masked faces, we found the expected result—that all emotions that are strongly expressed by the mouth area (e.g., the "smiling mouth" for happy faces or drawing down the labial angles for sad faces) were particularly impaired when a mask covered the mouth area.

In the present study, we further addressed the question of whether emotional intelligence (EI) is linked to the ability to assess facial emotions (with and without masks). However, neither ability-based nor self-reported EI was significantly linked to performance or confidence ratings. Due to the low internal consistency of the SREIS in this sample, the respective results should be interpreted with caution. We also did not find a relationship between attitude toward wearing masks and ability or confidence—so even people who had negative attitudes about using face masks were not worse at or less sure about identifying emotions.

Most of our effects were based on confidence as the dependent variable. When analyzing who was specifically affected by face masks, we found that people who were high performers in the condition without masks were more affected than others. However, this was true only for the confidence ratings but not for actual performance. We did not find an effect of participants' sex on performance or confidence. Similarly, age had no effect.

Taken together, we were able to detect clear impairments in the ability to read facial emotions as soon as a face was partly covered by a face mask. With the exception of disgust, where we found a dramatic reduction in performance and confidence, most people were less impaired than one might think, considering how much the faces were covered. With an average performance level of 73.3%, participants were much better than chance, a level that had similarly been observed in children only recently (Carbon and Serrano, 2021).

It is important to consider that we used high-quality face stimuli, which had been tested for clear emotional expressions and were characterized by perfect illumination and a frontal perspective. Moreover, participants were able to look at the pictures without time pressure and with the opportunity to fixate perfectly. Such ideal presentations are not available in everyday life, where faces have to be read in complex situations (Yang and Huang, 1994) and where time to inspect the counterpart is limited because of other task requirements or cultural factors, such as maximally accepted eye fixation durations (Haensel et al., 2021). In other words, in everyday life, the general performance of recognizing emotions is probably much lower, and facial masks would be an additional burden. We do not really know how much we gain, on the other side, when encountering faces in reality, e.g., by using dynamic 3D information (see Dobs et al., 2018).

Still, does such reduced information jeopardize communication? Basing the understanding of our counterpart's emotional or mental state on only facial expressions would be pretty inefficient. More than this, reliance on just one source of information would be reckless and improbable from an evolutionary point of view. Typically, highly developed social species such as humans use different channels of sensory inputs (Shi and Mueller, 2013) and build mental models to predict plausible outcomes (Johnson-Laird, 2010). Furthermore, humans can disambiguate difficult situations (e.g., the uncertain status of a counterpart) by verbally posing questions or simply by waiting for additional information.

On the basis of a comparison of data from 2020 to 2021, we showed that people apparently did not easily adapt their emotion reading skills but people can use additional sources of information. We only tested the loss of information in one channel, but other researchers collected supplemental information (for a short list of ways to cope with the loss of information, see Mheidly et al., 2020).

As a conclusion we speculate that the first important step toward facilitating communication among people who wear face masks would be to raise awareness regarding the challenges to communication that hail from the loss of facial information. Additional steps are to utilize information on body language and gestures. Considering the social situation, we are currently in, we can also use scripts and schemata typically employed in such situations, which help us predict what others will feel and how they will be affected by the current situation. Lastly, we can directly approach our counterparts and explicitly ask them whether pieces of information are missing.

The COVID-19 pandemic comes as a worldwide crisis with specific challenges. The impaired ability to read facial information is definitely one of these challenges. However, intelligent species adapt adequately to better cope with such a situation by developing new means of communication and social interaction. In the end, true social competence manifests itself in the ability to adapt to given task demands. If we use this ability flexibly, we will effectively cope with the communicative challenges inherent in the present pandemic.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/rfmv7.

ETHICS STATEMENT

We obtained ethical approval for the general psychophysical study procedure from the local ethics committee of the University of Bamberg (Ethikrat). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

C-CC and AS had the initial idea for this research. C-CC made the statistics and the figures and wrote the initial paper. MH enriched the statistics by adding consistency scores. AS and MH revised the manuscript. All authors contributed to the article and approved the submitted version.

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REFERENCES

Barton, K. (2019). MuMIn: Multi-Model Inference. R package version 1.6. Available at: https://CRAN.R-project.org/package=MuMIn (Accessed January 27, 2022).

Bassili, J. N. (1979). Emotion recognition: the role of facial movement and the relative importance of upper and lower areas of the face. *J. Pers. Soc. Psychol.* 37, 2049–2058. doi: 10.1037/0022-3514.37.11.2049

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Bombari, D., Schmid, P. C., Schmid Mast, M., Birri, S., Mast, F. W., and Lobmaier, J. S. (2013). Emotion recognition: the role of featural and configural face information. *Q. J. Exp. Psychol.* 66, 2426–2442. doi: 10.1080/17470218.2013.789065

Brackett, M. A., Rivers, S. E., Shiffman, S., Lerner, N., and Salovey, P. (2006). Relating emotional abilities to social functioning: a comparison of self-report and performance measures of emotional intelligence. *J. Pers. Soc. Psychol.* 91, 780–795. doi: 10.1037/0022-3514.91.4.780

Bruce, V., and Young, A. (1986). Understanding face recognition. *Br. J. Psychol.* 77, 305–327. doi: 10.1111/j.2044-8295.1986.tb02199.x

Carbon, C. C. (2011). The first 100 milliseconds of a face: on the microgenesis of early face processing. *Percept. Mot. Skills* 113, 859–874. doi: 10.2466/07.17.22.PMS.113.6.859-874

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C. C. (2021). About the acceptance of wearing face masks in times of a pandemic. *i-Perception* 12, 1–14. doi: 10.1177/20416695211021114

Carbon, C. C., Faerber, S. J., Augustin, M. D., Mitterer, B., and Hutzler, F. (2018). First gender, then attractiveness: indications of gender-specific attractiveness processing via ERP onsets. *Neurosci. Lett.* 686, 186–192. doi: 10.1016/j.neulet.2018.09.009

Carbon, C. C., and Leder, H. (2005). When feature information comes first! Early processing of inverted faces. *Perception* 34, 1117–1134. doi: 10.1068/p5192

Carbon, C. C., and Serrano, M. (2021). The impact of face masks on the emotional reading abilities of children—A lesson from a joint school–university project. *i-Perception* 12, 1–17. doi: 10.1177/20416695211038265

Dobs, K., Bülthoff, I., and Schultz, J. (2018). Use and usefulness of dynamic face stimuli for face perception studies: a review of behavioral findings and methodology. [mini review]. *Front. Psychol.* 9:1355. doi: 10.3389/fpsyg.2018.01355

Duchaine, B. C., Germine, L., and Nakayama, K. (2007). Family resemblance: ten family members with prosopagnosia and within-class object agnosia. *Cogn. Neuropsychol.* 24, 419–430. doi: 10.1080/02643290701380491

Duchaine, B. C., and Nakayama, K. (2006). The Cambridge face memory test: results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia* 44, 576–585. doi: 10.1016/j.neuropsychologia.2005.07.001

Ebner, N. C., Riediger, M., and Lindenberger, U. (2010). FACES-A database of facial expressions in young, middle-aged, and older women and men: development and validation. *Behav. Res. Methods* 42, 351–362. doi: 10.3758/BRM.42.1.351

Fischer, A. H., Gillebaart, M., Rotteveel, M., Becker, D., and Vliek, M. (2012). Veiled emotions: the effect of covered faces on emotion perception and attitudes. *Soc. Psychol. Personal. Sci.* 3, 266–273. doi: 10.1177/1948550611418534

Gessler, S., Nezlek, J. B., and Schütz, A. (2021). Training emotional intelligence: does training in basic emotional abilities help people to improve higher emotional abilities? *J. Posit. Psychol.* 16, 455–464. doi: 10.1080/17439760.2020.1738537

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking emotions: face masks impair how we read emotions. *Front. Psychol.* 12:669432. doi: 10.3389/fpsyg.2021.669432

Green, P., and MacLeod, C. J. (2016). Simr: an R package for power analysis of generalised linear mixed models by simulation. *Methods Ecol. Evol.* 7, 493–498. doi: 10.1111/2041-210X.12504

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Haensel, J. X., Smith, T. J., and Senju, A. (2021). Cultural differences in mutual gaze during face-to-face interactions: a dual head-mounted eye-tracking study. *Vis. Cogn.* 1-16, 1–16. doi: 10.1080/13506285.2021.1928354

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., and Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science* 293, 2425–2430. doi: 10.1126/science.1063736

Herlitz, A., and Lovén, J. (2013). Sex differences and the own-gender bias in face recognition: a meta-analytic review. *Vis. Cogn.* 21, 1306–1336. doi: 10.1080/13506285.2013.823140

Herpertz, S., Schütz, A., and Nezlek, J. (2016). Enhancing emotion perception, a fundamental component of emotional intelligence: using multiple-group SEM to evaluate a training program. *Personal. Individ. Differ.* 95, 11–19. doi: 10.1016/j.paid.2016.02.015

Hodzic, S., Scharfen, J., Ripoll, P., Holling, H., and Zenasni, F. (2018). How efficient are emotional intelligence trainings: a meta-analysis. *Emot. Rev.* 10, 138–148. doi: 10.1177/1754073917708613

Hole, G., and George, P. (2011). Evidence for holistic processing of facial age. *Vis. Cogn.* 19, 585–615. doi: 10.1080/13506285.2011.562076

Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdimal, V., van der Westhuizen, H.-M., et al. (2021). An evidence review of face masks against COVID-19. *Proc. Natl. Acad. Sci.* 118:e2014564118. doi: 10.1073/pnas.2014564118

Johnson-Laird, P. N. (2010). Mental models and human reasoning. *Proc. Natl. Acad. Sci. U. S. A.* 107, 18243–18250. doi: 10.1073/pnas.1012933107

Joseph, D. L., and Newman, D. A. (2010). Emotional intelligence: an integrative meta-analysis and cascading model. *J. Appl. Psychol.* 95, 54–78. doi: 10.1037/a0017286

Karle, K. N., Ethofer, T., Jacob, H., Bruck, C., Erb, M., Lotze, M., et al. (2018). Neurobiological correlates of emotional intelligence in voice and face perception networks. *Soc. Cogn. Affect. Neurosci.* 13, 233–244. doi: 10.1093/scan/nsy001

Köppe, C., Held, M. J., and Schütz, A. (2019). Improving emotion perception and emotion regulation through a web-based emotional intelligence training (WEIT) program for future leaders. *Int. J. Emot. Educ.* 11, 17–32. doi: 10.20378/irb-46523

Koydemir, S., and Schütz, A. (2012). Emotional intelligence predicts components of subjective well-being beyond personality: a two-country study using self- and informant reports. *J. Posit. Psychol.* 7, 107–118. doi: 10.1080/17439760.2011.647050

Kret, M. E., and de Gelder, B. (2012). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Mayer, J. D., Roberts, R. D., and Barsade, S. G. (2008a). Human abilities: emotional intelligence. *Annu. Rev. Psychol.* 59, 507–536. doi: 10.1146/annurev.psych.59.103006.093646

Mayer, J. D., and Salovey, P. (1997). "What is emotional intelligence?" in *Emotional Development and Emotional Intelligence: Implications for Educators*. eds. P. Salovey and D. Sluyter (New York, NY: Basic Books), 3–31.

Mayer, J. D., Salovey, P., and Caruso, D. R. (2008b). Emotional intelligence: new ability or eclectic traits? *Am. Psychol.* 63, 503–517. doi: 10.1037/0003-066X.63.6.503

Mheidly, N., Fares, M. Y., Zalzale, H., and Fares, J. (2020). Effect of face masks on interpersonal communication during the COVID-19 pandemic. *Front. Public Health* 8:582191. doi: 10.3389/fpubh.2020.582191

Mishra, M. V., Likitlersuang, J., Wilmer, J. B., Cohan, S., Germine, L., and DeGutis, J. M. (2019). Gender differences in familiar face recognition and the influence of sociocultural gender inequality. *Sci. Rep.* 9:17884. doi: 10.1038/s41598-019-54074-5

Mitze, T., Kosfeld, R., Rode, J., and Wälde, K. (2020). Face masks considerably reduce COVID-19 cases in Germany. *Proc. Natl. Acad. Sci.* 117, 32293–32301. doi: 10.1073/pnas.2015954117

Morey, R. D. (2008). Confidence intervals from normalized data: a correction to Cousineau (2005). *Tutorials Quant. Methods Psychol.* 4, 61–64. doi: 10.20982/tqmp.04.2.p061

Østergaard Knudsen, C., Winther Rasmussen, K., and Gerlach, C. (2021). Gender differences in face recognition: the role of holistic processing. *Vis. Cogn.* 29, 379–385. doi: 10.1080/13506285.2021.1930312

Pavlova, M. A., and Sokolov, A. A. (2021). Reading covered faces. *Cereb. Cortex* 32, 249–265. doi: 10.1093/cercor/bhab311

R Core Team (2021). R: A Language and Environment for Statistical Computing. Available at: http://www.R-project.org/ (Accessed January 27, 2022).

Ramachandra, V., and Longacre, H. (2022). Unmasking the psychology of recognizing emotions of people wearing masks: the role of empathizing, systemizing, and autistic traits. *Personal. Individ. Differ.* 185:111249. doi: 10.1016/j.paid.2021.111249

Rhodes, G., Hayward, W. G., and Winkler, C. (2006). Expert face coding: configural and component coding of own-race and other-race faces. *Psychon. Bull. Rev.* 13, 499–505. doi: 10.3758/BF03193876

Schmidtmann, G., Logan, A. J., Carbon, C. C., Loong, J. T., and Gold, I. (2020). In the blink of an eye: Reading mental states from briefly presented eye regions. *I-Perception* 11:2041669520961116. doi: 10.1177/2041669520961116

Schneider, T. M., Hecht, H., and Carbon, C. C. (2012). Judging body weight from faces: The height-weight illusion. *Perception* 41, 121–124. doi: 10.1068/p7140

Shi, Z., and Mueller, H. (2013). Multisensory perception and action: development, decision-making, and neural mechanisms. *Front. Integr. Neurosci.* 7:81. doi: 10.3389/fnint.2013.00081

Steinmayr, R., Schütz, A., Hertel, J., and Schröder-Abé, M. (2011). "German adaptation of the mayer-salovey-caruso emotional intelligence test (MSCEIT)," in *Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT)*. eds. J. D. Mayer, P. Salovey and D. R. Caruso (Huber).

Taylor, S., and Asmundson, G. J. G. (2021). Negative attitudes about facemasks during the COVID-19 pandemic: the dual importance of perceived ineffectiveness and psychological reactance. *PLoS One* 16:e0246317. doi: 10.1371/journal.pone.0246317

Vöhringer, M., Schütz, A., Geßler, S., and Schröder-Abé, M. (2020). SREIS-D: die deutschsprachige version der self-rated emotional intelligence scale. *Diagnostica* 66, 200–210. doi: 10.1026/0012-1924/a000248

Willis, J., and Todorov, A. (2006). First impressions: making up your mind after a 100-ms exposure to a face. *Psychol. Sci.* 17, 592–598. doi: 10.1111/j.1467-9280.2006.01750.x

Wingenbach, T. S. H., Ashwin, C., and Brosnan, M. (2018). Sex differences in facial emotion recognition across varying expression intensity levels from videos. *PLoS One* 13:e0190634. doi: 10.1371/journal.pone.0190634

Yang, G., and Huang, T. S. (1994). Human face detection in a complex background. *Pattern Recogn.* 27, 53–63. doi: 10.1016/0031-3203(94)90017-5

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The Recognition of Facial Expressions Under Surgical Masks: The Primacy of Anger

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Background: The need to wear surgical masks in everyday life has drawn the attention of psychologists to the negative effects of face covering on social processing. A recent but not homogeneous literature has highlighted large costs in the ability to recognize emotions.

Methods: Here it was investigated how mask covering impaired the recognition of facial mimicry in a large group of 220 undergraduate students. Sex differences in emotion recognition were also analyzed in two subgroups of 94 age-matched participants. Subjects were presented with 112 pictures displaying the faces of eight actors (4 women and 4 men) wearing or not wearing real facemasks, and expressing seven emotional states (neutrality, surprise, happiness, sadness, disgust, anger and fear). The task consisted in categorizing facial expressions while indicating the emotion recognizability with a 3-point Likert scale. Scores underwent repeated measures ANOVAs.

Results: Overall, face masking reduced emotion recognition by 31%. All emotions were affected by mask covering except for anger. Face covering was most detrimental to sadness and disgust, both relying on mouth and nose expressiveness. Women showed a better performance for subtle expressions such as surprise and sadness, both in masked and natural conditions, and men for fear recognition (in natural but especially masked conditions).

Conclusion: Anger display was unaffected by masking, also because corrugated forehead and frowning eyebrows were clearly exposed. Overall, facial masking seems to polarize non-verbal communication toward the happiness/anger dimension, while minimizing emotions that stimulate an empathic response in the observer.

Keywords: emotions, face masking, facial expression, face processing, sex difference, empathy

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INTRODUCTION

It is known that surgical masks (used pervasively to counter the transmission of coronavirus) might negatively affect and impair social processing. Impairment might concern the recognition of face identity (Carragher and Hancock, 2010; Noyes et al., 2021), emotion reading (Roberson et al., 2012; Carbon, 2020; Ruba and Pollak, 2020; Calbi et al., 2021; Grundmann et al., 2021; Marini et al., 2021; Carbon et al., 2022), trustworthiness judgment (Biermann et al., 2021), face likability and closeness impression (Grundmann et al., 2021), as well as speech comprehension (Singh et al., 2021). Relatedly, previous literature showed that face blurring impairs the understanding of emotional signals including body language (Proverbio et al., 2018). Although emotions conveyed by bodily expressions are quite easily recognizable (de Gelder et al., 2015), face obscuration reduces pantomime comprehension in healthy subjects, as opposed to patients with bilateral amygdala damage (Adolphs et al., 2003). This indicates how facial mimicry is crucial in nonverbal communication. For example, when facial expressions are incongruent with bodily expressions (of anger, for instance) response times are much slower during a matching-to-sample task in controls (Kret and de Gelder, 2013), thus suggesting that bodily expressions are better recognized when accompanied by a face that expresses the same emotion (Meeren et al., 2005).

To investigate at which extent face covering impaired social communication Grundmann et al. (2021) performed a large study on 191 individuals of different ages and sexes and found that facemasks diminished people's ability to accurately categorize facial expressions and affected the perceptions of person trustworthiness, likability, and closeness.

Generally, the mouth region is thought to be most informative for happy, surprised and disgusted expressions, while the eyes area is considered more informative for fearful and angry expressions. For example, the white sclera expansion, typical of fear display, is especially at the basis of its innate recognition (e.g., Jessen and Grossmann, 2014; Barrett, 2018). Both the mouth and eyes areas are informative for neutral and sad expressions (Smith et al., 2005;Wegrzyn et al., 2017). In addition, joy can very well detected through the smiling mouth, but especially the "smiling" eyes. Years of psychological (e.g., Ekman et al., 1998) and lately engineering research on pattern recognition (e.g., Ugail and Al-dahoud, 2019) have shown that the more reliable indicators of a genuine happy facial expression are indeed the eyes. Angry facial expressions are associated with a strong activation of the corrugator supercilii (i.e., the muscle involved in frowning), whereas happy facial expressions are associated with a strong activation of the zygomaticus major, (the muscle involved in smiling) (Rymarczyk et al., 2019). Based on the above findings we expected lower costs in accuracy due to the covering of the lower part of the face (face masking) during recognition of anger and happiness expressions, but the available literature was not completely homogeneous at this regard.

Noyes et al. (2021) recently explored the effect of masks and sunglasses wearing on familiar and unfamiliar face matching and emotion categorization in 100 participants. They found that, while masks did not reduce the recognition of angry faces, facial expressions of disgust, happy, fear and surprise were most affected by it. A large reduction in categorization accuracy for disgust expressions was found in particular. Sadness detection was difficult both mask less and with mask covering, so that the performance was not significantly impaired by masking. Results are not fully consistent across studies. In a recent study by Marini et al. (2021) investigating the impact of facemasks on emotion recognition (but only with three emotions) they showed an impaired recognition of sad and fearful expressions in the masked condition, with no effect on neutral expressions. Among the three expressions, sadness was the most affected and happiness the least affected. In this study, sadness was more hardly detected with mask covering the mouth area.

One of the problems with the available studies is that many of them digitally applied a mask or a foulard on the face picture in order to create identically expressive faces, across the masked vs. non-masked category (e.g., Carragher and Hancock, 2010; Carbon, 2020; Calbi et al., 2021; Grundmann et al., 2021; Marini et al., 2021; Carbon et al., 2022). While this procedure might assure an optimal matching between masked and unmasked expressions, however it lacks likelihood and ecological value. Indeed, digitally applied masks are not stretched by the facial expression thus reducing the verisimilitude. Furthermore, they deprive the visual image of details that are present in the real masked face, such as mask sucking or folding. In reality, surgical masks are, for example, deformed by the vertical opening of the mouth in expressions like surprise or laughing, or during verbal speech; likewise, they are stretched horizontally for smiling. Indeed the masks adapt to, and reveal, the underneath muscular movements, which can be picked up by an observer. In order to maintain the visibility of mask bending and stretching due to underneath facial mimicry, in this study, actors wore real surgical masks during shooting. Several repetitions and much effort was devoted to the perfect matching between expressions produced with or without masks.

The aim of the study was to gain clear knowledge on the effects of face masking on the comprehensibility of a large variety of facial expressions (i.e., the six basic Ekman emotions: fear, anger, joy, sadness, disgust, and surprise plus neutrality) by using real and non-digital facemasks, unlike many of the previous studies quoted above. In fact, it is possible that digital masks further limited the possibility of recognizing facial mimicry because they are fixed and do not show dynamic deformations of the fabric, made possible by its elasticity. For example, real masks can show inhalation-related sucking associated with startle reaction in the surprise or fear expressions. Again, they can also show vertical and horizontal stretching of the tissue due to smiling or nose wrinkling. Therefore, it is possible that emotion recognition under digital facemasks was currently under-estimated.

In addition, we wished to investigate if face masking affected the two sexes differently. According to the available psychological and neuroscientific literature, overall, females would be more accurate in identifying emotional facial expressions then males (e.g., McClure, 2000; Montagne et al., 2005; Proverbio et al., 2006; Proverbio, 2021). Indeed, a recent study involving perception of masked faces (Grundmann et al., 2021) showed that being a man was associated with a reduced accuracy in emotion recognition than being a woman, without specific interactions with face masking conditions.

MATERIALS AND METHODS

Participants

220 undergraduate students of local University self-recruited through online advertisement posted on the student's web site. Six of them were excluded because older than 35 years. They aged between 18 and 35 years (mean = 21.617, SD = 2.91) and 47 of them were males). Experiments were conducted with the understanding and written consent of each participant according

to the Declaration of Helsinki (BMJ 1991; 302: 1194) with approval of the Ethical Committee of the Psychology department of local University approved the study (protocol number: RM-2021-401). It was conducted online from June 25 until July 8 2021 and programmed in Google forms https://www.google.com/forms. Participation was free and not rewarded.

Stimuli

10 actors (master psychology students) of Caucasian ethnicity were recruited (five females and five males) aging 23 years on average (SD = 1.333) for photos taking. High-resolution pictures of their faces were self- taken with a cell phone at about 40 cm of distance in light controlled conditions, while standing up against a white wall. Actors were required to avoid wearing earrings, glasses, make up, hairpins, pliers, any type of hair embellishments, mustaches, beard. They were also instructed to wear a black t-shirt and gather the hair behind the head. The pictures of two actors were discarded in that showing a different mimicry in the natural vs. masked condition; their pictures were therefore used only as stimuli for the training phase, to accustom the subjects to the task, without showing them the faces selected for the experimental phase. For each of the seven emotions, actors were instructed to imagine a vivid emotional state, while concentrating on a specific autobiographic scenario through the Stanislavsky method, and express it spontaneously while ignoring the presence/lack of surgical masks. For "surprise" emotion, they were instructed to think of a positive surprise. They trained repeatedly in order to reach the same degree of intensity across subjects and emotions (see **Figure 1** for some examples). Each of the 10 actors provided written consent and filled in the privacy release form.

Stimulus set was validated on a group of 50 students (25 females, 24 males and 1 gender fluid) aging on average 23.7 years (min = 17, max = 34 years). All participants had normal vision, no neurological or psychiatric deficits and possessed diploma, BA or Master degrees. Participants were shown, randomly mixed and once at a time, the 56 pictures relative to the seven facial expressions acted by the eight female and male actors. Subjects were required to rapidly observe the picture and decide which one of the seven emotions typed below was more appropriate to describe the viewed facial expression, by clicking a check mark within a few seconds. Pictures were displayed at the center of the screen and the experimental session lasted 10 min.

Overall performance for correctly identifying facial emotions in unmasked faces was remarkably high = 87.35% (with a chance rate of 16.7%). No participant performed below an overall rate of 75.0%. In more details, accuracy was 98.47% for joy, 86.73% for surprise, 80.1% for sadness, 89.29% for anger, 72.70% for fear, 85.97% for disgust and 98.21% for neutrality. These recognition rates (in line with the data reported by Carbon, 2020; Carbon et al., 2022) outperform the accuracy of recognizing facial expressions reported by other studies in the literature (e.g., 57.85% for anger and disgust in Aviezer et al. (2008) and 57.85 for negative emotions in Derntl et al. (2009) thus supporting the qualitative validity of the stimuli.

Stimulus set was also evaluated for facial attractiveness by a further group of 12 students (seven females and five males) aged between 18 and 25 years. Judges were requested to evaluate the attractiveness of neutral unmasked pictures of all identities, by using a 3-point Likert scale, where 1 stood for "not attractive," 2 for "average" and 3 for "attractive." The results showed a perfect balance across the two sexes and indicated an "average" degree of attractiveness for the facial stimuli (Females = 1.83; SD = 0.78; Males = 1.82; SD = 0.76). This characteristic of stimuli promotes the generalizability of results to the normally looking population

Procedure

After giving written and informed consent participants were administered a questionnaire about demographic information (such as age, sex, manual dexterity, educational qualification and e-mail address). This section was followed by the emotion-recognition task, consisting in 112 experimental trials, in which participants were first shown a portrait photograph of an adult face to be inspected for about 2 s. The images were equiluminant as assessed by subjecting their luminance values to an analysis of variance ($F = 0.099$, $p = 0.992$). Photos were in color, had the same size (3.37 cm × 5 cm; 199 × 295 pixels; 3° 22′ × 5°) and were displayed at the center of the screen, on a white background.

Immediately below the face, there was a list of words (neutrality, happiness, surprise, fear, anger, sadness, disgust), from which they had to select the emotion that they deemed the most appropriate to characterize the face. Next, participants judged how clearly they considered the expression recognizable on a 3-point Likert scale (ranging from "1 = not much" to "3 = very much"). The original wording was in Italian. The emotion was scored 0 if a different incorrect expression was selected. 5 s were allowed for perceiving and responding to the two queries. Participants were instructed to observe one face at a time and to respond within 5 s, not missing any answer. Only one choice per face was allowed. The task lasted about 15 min.

Data Analysis

The individual scores obtained from each individual, for each of the 7 facial expressions and condition, underwent a 3-ways repeated-measures ANOVA whose factors of variabilities were: one between-groups named "sex" (with 2 levels, female and male), and two within-groups named "condition" (with 2 levels, natural and masked) and "emotion" (with 7 levels, happiness, neutrality, surprise, anger, sadness, fear, disgust).

In order to properly assess the statistical effect of the sex of participants (who were females in majority) in a balanced population, two subgroups of participants were created: the group of males comprised all male participants recruited ($N = 47$) and a blind selection of females ($N = 47$) chose on the basis of their date of birth (by paring each of the male with a same-age female). The statistical power achieved by the current sample size ($N = 94$) was computed using the program G*Power 3.1 (Faul et al., 2009) for comparing 2 independent groups.

As a result of this blind procedure, the age of the two sub-groups was identical (males: 23.042, fameless: 23.042). A 3-ways repeated-measures ANOVA was also performed on the data relative to this sample. Factors of variabilities were: one between-groups named "sex" (with 2 levels, female and male), and two within-groups named "condition" (with 2

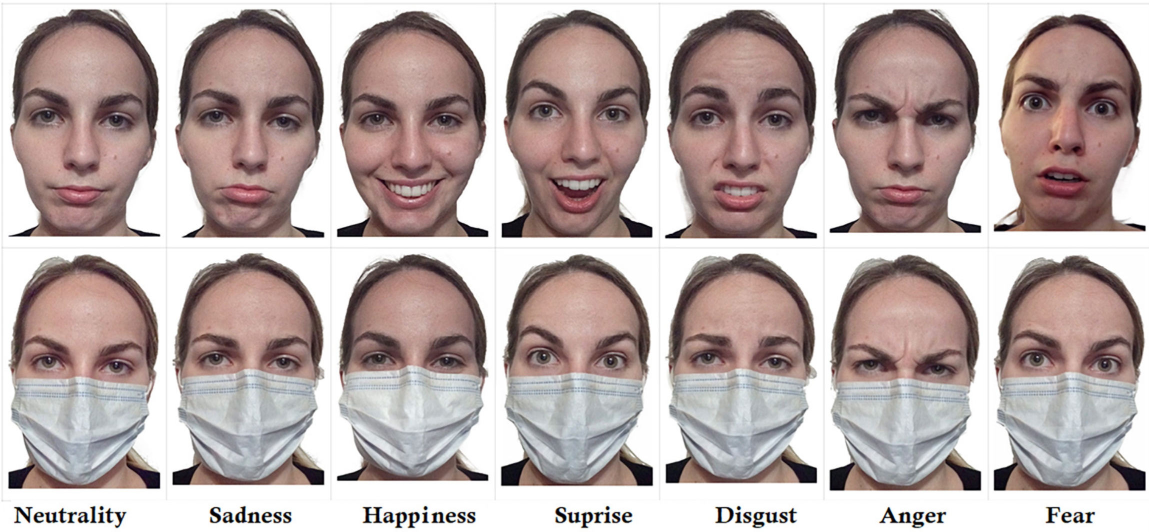

FIGURE 1 | Example of stimuli (facial expressions) in the natural and masked condition. Overall, stimuli were created by taking photographs of natural expressions of eight actors (four male and four females) concentrated on their inner imaginary emotional state, through the Stanislavsky method. Masks were worn in reality and not digitally recreated. This revealed, for example the mouth/lips contraction associated with anger, the large mouth opening associated with disgust, the air intake (inhalation) characteristic of surprise or fear resulting in evident mask sucking.

levels, natural and masked) and "emotion" (with 7 levels, happiness, neutrality, surprise, anger, sadness, fear, disgust). Multiple *post hoc* comparisons were performed using Tukey's test. Greenhouse-Geisser correction was applied in case of epsilon < 1 and epsilon corrected p value were computed.

RESULTS

The factor condition was statistically significant [$F(1,212) = 212; p < 0.001$, $\varepsilon = 1$], with emotion recognizability being higher in the natural [2.31, standard error (SE) = 0.02] than masked (1.59, SE = 0.02) condition. The factor emotion was also significant [$F(6,1272) = 191$; $p < 0.001$, $\varepsilon = 0.79$, ε-corrected p value = 0.001]. *Post hoc* comparisons showed that overall positive emotions were recognized more easily than negative emotions ($p < 0.001$), except for anger, as shown in **Figure 2** (neutral = 2.422, SE = 0.029; happy = 2.3, SE = 0.03; surprise = 2.02; SE = 0.03; anger = 2.22, SE = 0.03; sadness = 1.788, SE = 0.02; fear = 1.48; SE = 0.04; disgust = 1.42, SE = 0.02.). Happiness was recognized more easily ($p < 0.001$), the recognizability of fear and disgust was equally poor, while that of neutral and angry expressions was equally high.

Surgical masks (covering the nose and mouth area) strongly reduced recognizability of all emotions, as shown by the statistical significance of condition × emotion [$F(6,1272) = 160$; $p < 0.001$, $\varepsilon = 0.911$, ε-corrected p value = 0.001], except for anger. *Post hoc* comparisons showed that neutral and happy expressions were equally well recognizable under the mask, but worse than angry expressions. Again, negative emotions such as disgust, sadness and fear were much poorly recognized than positive emotions in masked conditions. **Figure 3** shows the mean scores for each facial expression as a function of the masking condition. Negative emotions such as sadness and disgust, more relying on the nose and mouth area expressivity, were most penalized by mask covering.

The sex of viewer affected the ability to recognize the emotions regardless of face covering, as shown by the significance of emotion × sex interaction [$F(6,1272) = 4.14$; $p < 0.001$, $\varepsilon = 0.776$, ε-corrected p value = 0.001]. The ANOVA performed on the two subgroups of 47 males and 47 females yielded the same significances as the main ANOVA, i.e.: condition ($p < 0.001$), emotion ($p < 0.001$), emotion × condition ($p < 0.001$) and emotion × sex interaction [$F(6,552) = 4.138$; $p < 0.001$, $\varepsilon = 0.778$, ε-corrected p value = 0.001].

As for the last interaction and similarly to ANOVA applied to the whole population (see **Figure 4** for mean values and SEs), *post hoc* showed that while women were better at recognizing surprise ($p < 0.004$) and sadness ($p < 0.05$), males were better at recognizing fear expressions ($p < 0.005$). Simple effect analysis showed that this male advantage in recognizing fear was even stronger (see **Figure 5**) in the masked conditions ($p < 0.004$).

DISCUSSION

In the natural (mask less) conditions, positive emotions (happiness, neutrality, positive surprise) were recognized more accurately than negative emotions such as fear, sadness or disgust. This positive/negative valence distinction is based on the dichotomy on approach/avoidance attitude to emotions supported by previous neuroimaging and electrophysiological literature (Davidson, 1995; Balconi et al., 2017). Overall, masking heavily affected emotion comprehension with a 31% decay

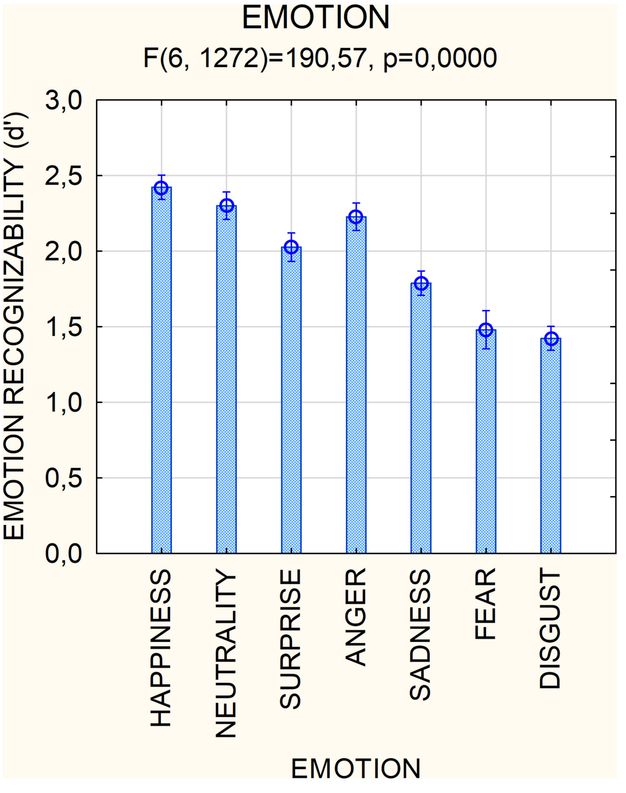

FIGURE 2 | Mean scores of recognizability (along with SE values) attributed by participants (*N* = 214) to the various facial expressions regardless of masking condition. Scale ranged from 0 = "not much recognizable" to 3 = "very well recognizable".

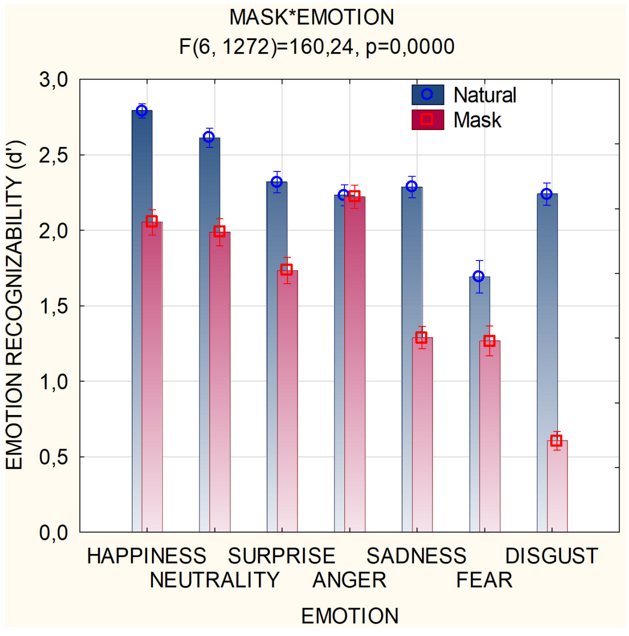

FIGURE 3 | Mean scores of recognizability (along with SE values) attributed by participants (*N* = 214) to the various facial expressions as a function of masking condition. Scale ranged from 0 = "not much recognizable" to 3 = "very well recognizable".

in recognizability (namely, going from 2.31 in the natural condition to 1.59 in the masked condition, on a scale where 0 indicated "not much recognizable" and 3 stood for "very well recognizable"). Overall, these findings fit with previous recent literature showing how facemasks reduce emotion recognition accuracy (Roberson et al., 2012; Carbon, 2020; Ruba and Pollak, 2020; Calbi et al., 2021; Marini et al., 2021; Grundmann et al., 2021; Carbon et al., 2022). In our study, face masking was most detrimental for sadness and especially disgust detection, than positive emotions such as happiness. This pattern of results agrees with previous studies, for example Marini et al. (2021), finding that sadness was the most affected and happiness the least affected expression by face masking.

However, we found that mask covering did not affect the recognition of angry faces, which replicates some findings obtained with non-digital masks by Noyes et al. (2021) (see their **Figure** 7), who also found that the mask and sunglasses conditions did not significantly differ in the angry expressions. The primacy of anger among the biologically relevant emotions has been shown by several studies (e.g., Mancini et al., 2020).

Conversely, the emotional display whose recognition was most affected by mask covering was disgust (also in Noyes et al.'s, 2021 study). Indeed, disgust's more evident markers (nasiolabial lifting and grimacing and nose wrinkling) are hidden by surgical masks in the masking condition. At this regard it is known that successful recognition of anger versus disgust requires one to process information located in the eye/brow region (which was disclosed) as opposed to the mouth/nose region (which was covered by masks), respectively (Yitzhak et al., 2020). Again, in a study by Ponari et al. (2012) where emotion recognition was hampered by stimuli in which an upper or lower half-face showing an emotional expression was combined with a neutral half-face it was shown that neutral lower half-face interfered with recognition of disgust, whereas the neutral upper half (i.e., the eyes area) impaired the recognition of anger. This difference may probably explain the supremacy of anger and the poor recognition of disgust in the present study.

Women Better at Recognizing Sadness and Surprise

In our study, females outperformed males in the recognition of sadness and surprise. Several evidences in the literature consistently reported a similar pattern of results for both sadness (Montagne et al., 2005; Deng et al., 2016; Li et al., 2020) and surprise (Montagne et al., 2005). In addition, according to some investigations, women seem to be more sensitive to sadness whereas men seem to be more sensitive to anger (Brody et al., 1995; Deng et al., 2016; He et al., 2018). In another study by Montagne et al. (2005) women were reported to be significantly more accurate than men at identifying sadness and surprise. Furthermore, Li et al. (2020)'s study, performed in 1,063 participants varying in sex and age, reported that women

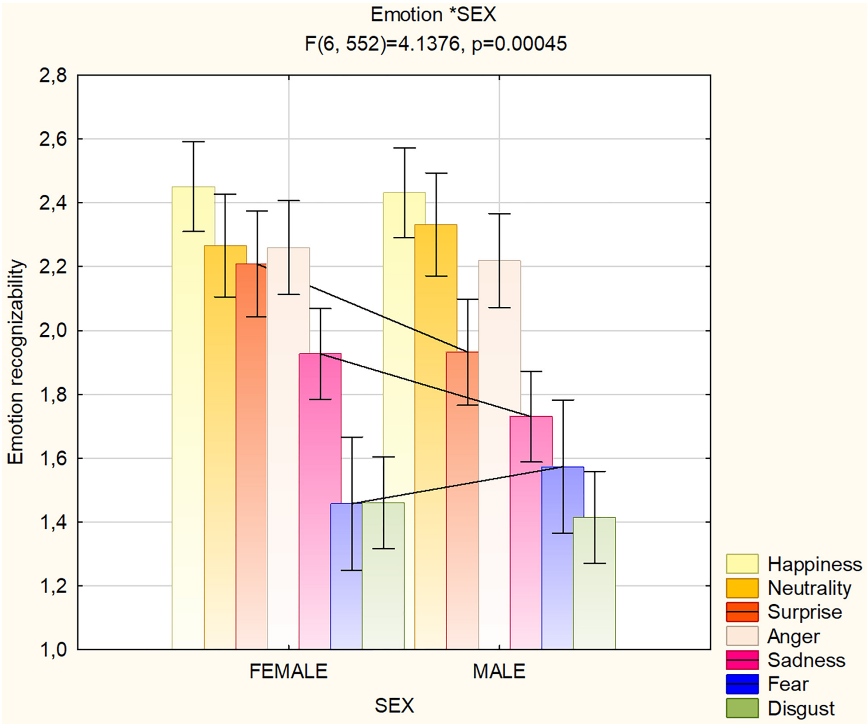

FIGURE 4 | Mean scores of recognizability (along with SE values) attributed by female and male participants (N = 94) to the various facial expressions as a function of masking condition.

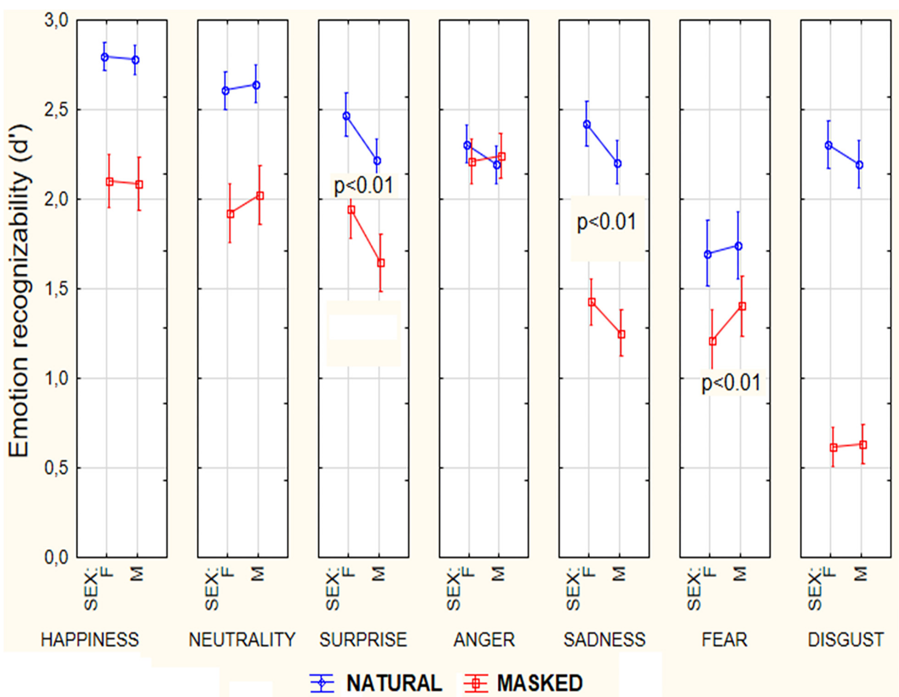

FIGURE 5 | Mean scores (along with SE values) of recognizability attributed by participants (N = 94) to the various facial expressions as a function of sex of viewers and masking condition. Scale ranged from 0 = "not much recognizable" to 3 = "very well recognizable".

performed significantly better at recognizing facial expressions of sadness and disgust.

As for the specific effect of masking, Grundmann et al. (2021) tested 191 participants (52.9% female) aging from 19 to 79 years and found that emotion-recognition accuracy declined for masked (vs. unmasked) faces. More interestingly, they showed lower accuracy to being male vs. female, being old (vs. young), and to seeing an old (vs. young) target face. In a study by Calbi et al. (2021) involving only three affective displays (neutrality, happiness and anger) it was found that female participants gave more negative ratings than male ones when evaluating angry and neutral facial expressions, and more positive ratings when evaluating happy facial expressions. This was discussed in terms of women' stronger sensibility to face expressivity and better decoding of emotions through facial expressions (e.g., McClure, 2000; Proverbio et al., 2007; Hall et al., 2010; Proverbio, 2021). Consistently, Hoffmann et al. (2010) found that women were better at identifying subtle, less intense emotions (such as sadness), but equally good at identifying clearly expressed emotions (such as fear). Apart from that, it is generally believed that women are more sensitive to emotional facial cues (Proverbio, 2017).

Men Better at Detecting Fear

In this study, males outperformed women in recognizing fearful expressions (especially masked ones). The increased male ability to recognize fear (relying mostly on the processing of the eyes area, with the typical sclera enlargement) when faces were covered by surgical masks, might depend on the fact the eyes were even more focally attended in the masked condition, being the only uncovered face area. However, Sullivan et al. (2017), investigating the percentage of time young women and men spent fixating the eyes and mouth areas of facial expressions (including fear), found that both sexes spent 63.6% of their time looking at the eyes (and 36.4% of the time at the mouth) with no difference across sexes.

In the literature, a male advantage in the processing of fearful expressions is not commonly found, except for an fMRI study, observing regional brain responses to face versus shape identification, in which men showed more significant modulations by both fear and anger affective traits than women (Li et al., 2020).

On a different verge, Riva et al. (2011) have instead found that the observers' ability to detect pain in a female face was lower than their ability to detect pain in male faces, i.e., that male pain faces are more easily processed at the reflexive level. Relatedly, Simon et al. (2006) in an fMRI study found that observing male (vs. female) individuals expressing pain activated in the observers a much greater threat-related response, including the activation of the ventromedial prefrontal cortex, posterior and anterior insula, somatosensory areas, and amygdala. In another study, where healthy subjects were provoked by money taken by an opponent and given the opportunity to retaliate, men showed a higher amygdala activation during provocation, and the amygdala activation correlated with trait anger scores in men, but not in women (Repple et al., 2018). As well-known amygdala nuclei are the brain structures most involved in fear and threat processing (Adolphs et al., 1995).

Summary

Overall, while face masking reduced the comprehension of all facial expressions but anger (conveying an aggressive display), it was most detrimental for sadness and especially disgust detection (conveying a second person, more passive negative state). The larger impairment for the recognition of the above expressions might depend on their mainly relying on the expressivity of mouth (especially sadness: Smith et al., 2005; Wegrzyn et al., 2017) and nose areas (especially disgust: Yitzhak et al., 2020; Noyes et al., 2021), which were covered by masks. Instead, the angry expression was totally unaffected by face masking. This effect, different from previous studies, might be related to the ecological use of real and non-digital masks, allowing a more complex analysis of facial patterns.

In general, women showed a better performance for positive emotions, both in masked and natural conditions, and men for fear recognition (in natural but especially masked conditions). At this regard, it might be interesting to consider that sex differences in the hemispheric activation for emotion processing were reported. Cahill et al. (2001) found that enhanced memory for emotional video clips was associated with activity of the right amygdala in men, and of the left amygdala in women. In addition, an fMRI study investigating the emotional response to odors by Royet et al. (2003) found a sex difference in the activation of the left orbitofrontal cortex, which was greater in women compared to men. On the other side, Bourne and Watling (2015) found that for males, but not females, greater reported use of negative emotion strategies was associated with stronger right hemisphere lateralization for processing negative emotions. In the light of the well know right/left asymmetry for negative/positive emotions (Canli et al., 1998; Davidson et al., 1999) these studies might provide the neural underpinnings for the higher male accuracy in fear recognition (right amygdala), and of the higher female accuracy for detecting subtle positive emotional cues (e.g., Calbi et al., 2021), but further investigations are certainly needed to reach a definitive conclusion.

More in general, our study suggests the opportunity of studying the effect of face masking with really worn facemasks (instead of digitally applied ones) because there might be a difference in the way masks elastically respond to underneath facial muscles contractions, by deforming and stretching differently as a function of the facial expression. Furthermore, the typical inhalation associated, for example, to the surprised or fearful reaction (startle response), which results in mask sucking, will not be observable with digitally applied masks.

In general, wearing masks hampers facial affect recognition, and it might be particularly challenging for individuals with neuropsychiatric or neurodevelopmental conditions (Pavlova and Sokolov, 2021).

In this study, face masking was strongly detrimental to the comprehension of emotional markers, especially of non-aggressive negative states (such as sadness, disgust and fear). The only expression, whose recognition was not impaired by masking was indeed anger (associated with angry eyes, forehead wrinkling and contraction of mouth and lip muscles).

The primacy of anger among other more subtle emotions (such as sadness) has been reported in previous other studies (Öhman, 1993; Esteves et al., 1994; Fox et al., 2000), who found increased psychophysiological responding to masked angry faces relative to masked happy faces. The present data showed how face masking was able to polarize emotion comprehension toward the negative/positive opposite dimensions (happiness/anger or approach/withdrawal), while causing a deficit in social interaction and communication of softer emotions that usually trigger an empathic resonance in the observer (sadness, fear, disgust). The limited recognition of distressed people's emotions might supposedly bring to a reduction of personal concern and empathic response (Israelashvili et al., 2020), within the population. This hypothesis strongly agrees with the recent findings by Rymarczyk et al. (2019), which, in a study using simultaneously recorded electromyography (EMG) and fMRI signals, showed that the perception of fear and disgust strongly activated brain regions involved in simulative processes and in empathy, such as mirror neurons (the fronto/parietal MNS) and limbic regions (e.g., the Anterior Insula (AI). Furthermore, the more empathic were the observers, the stronger was the reaction to these facial expressions. This seriously raises the question of a possible reduction in the observers' empathic capacity in the absence of subtle, lower facial cues covered by facemasks. In fact, the present pattern of results indicates a selective decrease in the ability to recognize emotions that normally stimulate an empathic response (e.g., sadness, disgust, and fear) in face masking conditions.

Study Limits

One possible limitation of this study is that static faces were used instead of dynamic videos for conveying affective information, since, naturally, the emotional valence of such stimuli is enhanced in naturalistic conditions (e.g., Ambadar et al., 2005; Rymarczyk et al., 2019). However, this study, and its novel pattern of results, should be compared with the pre-existing literature where masked static faces were used (Carbon, 2020; Ruba and Pollak, 2020; Calbi et al., 2021; Grundmann et al., 2021; Marini et al., 2021). It would be very interesting, in the near future, to investigate if this sparing of anger from the detrimental effects of masking can also be observed in dynamic conditions.

DATA AVAILABILITY STATEMENT

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Committee of University of Milano-Bicocca. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

AP conceived and planned the experiment, performed statistical analyses and data illustration, and wrote the manuscript. AC prepared the stimuli and carried out the data collection. AP and AC interpreted the data. Both authors provided critical feedback and helped shape the research, analysis and manuscript.

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REFERENCES

Adolphs, R., Tranel, D., and Damasio, A. R. (2003). Dissociable neural systems for recognizing emotions. *Brain Cogn.* 52, 61–69. doi: 10.1016/s0278-2626(03)00009-5

Adolphs, R., Tranel, D., Damasio, H., and Damasio, A. R. (1995). Fear and the human amygdala. *J. Neurosci.* 15, 5879–5891. doi: 10.1523/JNEUROSCI.15-09-05879.1995

Ambadar, Z., Schooler, J. W., and Cohn, J. F. (2005). Deciphering the enigmatic face: the importance of facial dynamics in interpreting subtle facial expressions. *Psychol. Sci.* 16, 403–410. doi: 10.1111/j.0956-7976.2005.01548.x

Aviezer, H., Hassin, R. R., Ryan, J., Grady, C., Susskind, J., Anderson, A., et al. (2008). Angry, disgusted, or afraid? Studies on the malleability of emotion perception. *Psychol. Sci.* 19, 724–732. doi: 10.1111/j.1467-9280.2008.02148.x

Balconi, M., Vanutelli, M. E., and Grippa, E. (2017). Resting state and personality component (BIS/BAS) predict the brain activity (EEG and fNIRS measure) in response to emotional cues. *Brain Behav*. 7:e00686. doi: 10.1002/brb3.686

Barrett, L. F. (2018). Seeing fear: it's all in the eyes? *Trends Neurosci.* 41, 559–563. doi: 10.1016/j.tins.2018.06.009

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: an experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Bourne, V. J., and Watling, D. (2015). Individual differences in emotion lateralisation and the processing of emotional information arising from social interactions. *Laterality* 20, 95–111. doi: 10.1080/1357650X.2014.925910

Brody, L. R., Lovas, G. S., and Hay, D. H. (1995). Gender differences in anger and fear as a function of situational context. *Sex Roles* 32, 47–78.

Cahill, L., Haier, R. J., White, N. S., Fallon, J., Kilpatrick, L., Lawrence, C., et al. (2001). Sex-related difference in amygdala activity during emotionally influenced memory storage. *Neurobiol. Learn. Mem.* 75, 1–9. doi: 10.1006/nlme.2000.3999

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: an online study on face covering. *Sci. Rep.* 11:2601. doi: 10.1038/s41598-021-81780-w

Canli, T., Desmond, J. E., Zhao, Z., Glover, G., and Gabrieli, J. D. E. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *Neuroreport* 9, 3233–3239. doi: 10.1097/00001756-199810050-00019

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C. C., Held, M. J., and Schütz, A. (2022). Reading emotions in faces with and without masks is relatively independent of extended exposure and individual difference variables. *Front. Psychol.* 17:856971. doi: 10.3389/fpsyg.2022.856971

Carragher, D. J., and Hancock, P. J. B. (2010). Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cogn. Res. Princ. Implic.* 5:59. doi: 10.1186/s41235-020-00258-x

Davidson, R. J. (1995). "Cerebral asymmetry, emotion and affective style," in *Brain Asymmetry*, eds R. J. Davidson and K. Hughdahl (Cambridge, MA: MIT Press), 361–387. doi: 10.1016/j.biopsycho.2005.06.010

Davidson, R. J., Abercrombie, H., Nitschke, J. B., and Putnam, K. (1999). Regional brain function, emotion and disorders of emotion. *Curr. Opin. Neurobiol.* 9, 228–234.

de Gelder, B., de Borst, A. W., and Watson, R. (2015). The perception of emotion in body expressions. *Wiley Interdiscip. Rev. Cogn. Sci.* 6, 149–158. doi: 10.1002/wcs.1335

Deng, Y., Chang, L., Yang, M., Huo, M., and Zhou, R. (2016). Gender differences in emotional response: inconsistency between experience and expressivity. *PLoS One* 11:e0158666. doi: 10.1371/journal.pone.0158666

Derntl, B., Seidel, E. M., Kainz, E., and Carbon, C. C. (2009). Recognition of emotional expressions is affected by inversion and presentation time. *Perception* 38, 1849–1862. doi: 10.1068/p6448

Esteves, F., Dimberg, U., and Öhman, A. (1994). Automatically elicited fear: conditioned skin conductance responses to masked facial expressions. *Cogn. Emot.* 8, 393–413.

Ekman, P., Friesen, W. V., and O'Sullivan, M. (1988). Smiles when lying. *J. Pers. Soc. Psychol.* 54, 414–420.

Faul, F., Erdfelder, E., Buchner, A., and Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav. Res. Methods* 41, 1149–1160. doi: 10.3758/BRM.41.4.1149

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., and Dutton, K. (2000). Facial expressions of emotion: are angry faces detected more efficiently? *Cogn. Emot.* 14, 61–92. doi: 10.1080/026999300378996

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hall, J. K., Hutton, S. B., and Morgan, M. J. (2010). Sex differences in scanning faces: Does attention to the eyes explain female superiority in facial expression recognition? *Cogn. Emot.* 24, 629–637.

He, Z., Liu, Z., Wang, J., and Zhang, D. (2018). Gender differences in processing fearful and angry body expressions. *Front. Behav. Neurosci.* 12:164. doi: 10.3389/fnbeh.2018.00164

Hoffmann, H., Kessler, H., Eppel, T., Rukavina, S., and Traue, H. C. (2010). Expression intensity, gender and facial emotion recognition: women recognize only subtle facial emotions better than men. *Acta Psychol.* 135, 278–283. doi: 10.1016/j.actpsy.2010.07.012

Israelashvili, J., Sauter, D., and Fischer, A. (2020). Two facets of affective empathy: concern and distress have opposite relationships to emotion recognition. *Cogn. Emot.* 34, 1112–1122. doi: 10.1080/02699931.2020.1724893

Jessen, S., and Grossmann, T. (2014). Unconscious discrimination of social cues from eye whites in infants. *Proc. Natl. Acad. Sci. U. S. A.* 111, 16208–16213. doi: 10.1073/pnas.1411333111

Kret, M. E., and de Gelder, B. (2013). When a smile becomes a fist: the perception of facial and bodily expressions of emotion in violent offenders. *Exp. Brain Res.* 228, 399–410. doi: 10.1007/s00221-013-3557-6

Li, G., Zhang, S., Le, T. M., Tang, X., and Li, C. R. (2020). Neural responses to negative facial emotions: sex differences in the correlates of individual anger and fear traits. *Neuroimage* 221:117171. doi: 10.1016/j.neuroimage.2020.117171

Mancini, C., Falciati, L., Maioli, C., and Mirabella, G. (2020). Threatening facial expressions impact goal-directed actions only if task-relevant. *Brain Sci.* 10:794. doi: 10.3390/brainsci10110794

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing and their development in infants, children, and adolescents. *Psychol. Bull.* 126, 424–453. doi: 10.1037/0033-2909.126.3.424

Meeren, H. K., van Heijnsbergen, C. C., and de Gelder, B. (2005). Rapid perceptual integration of facial expression and emotional body language. *Proc. Natl. Acad. Sci. U. S. A.* 102, 16518–16523. doi: 10.1073/pnas.0507650102

Montagne, B., Kessels, R. P. C., Frigerio, E., de Haan, E. H., and Perrett, D. I (2005). Sex differences in the perception of affective facial expressions: Do men really lack emotional sensitivity? *Cogn. Process.* 6, 136–141. doi: 10.1007/s10339-005-0050-6

Noyes, E., Davis, J. P., Petrov, N., Gray, K., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Öhman, A. (1993). "Fear and anxiety as emotional phenomenon: clinical phenomenology, evolutionary perspectives, and information-processing mechanisms," in *Handbook of Emotions*, eds M. Lewis and J. M. Haviland (New York, NY: Guildford Press), 511–536.

Pavlova, M. A., and Sokolov, A. A. (2021). Reading covered faces. *Cereb. Cortex* 14:bhab311. doi: 10.1093/cercor/bhab311

Ponari, M., Conson, M., D'Amico, N. P., Grossi, D., and Trojano, L. (2012). Mapping correspondence between facial mimicry and emotion recognition in healthy subjects. *Emotion* 12, 1398–1403. doi: 10.1037/a0028588

Proverbio, A. M. (2017). Sex differences in social cognition: the case of face processing. *J. Neurosci. Res.* 95, 222-234. doi: 10.1002/jnr.23817

Proverbio, A. M. (2021). Sex differences in the social brain and in social cognition. *J. Neurosci. Res.* [Online ahead of print]. doi: 10.1002/jnr.24787

Proverbio, A. M., Brignone, V., Matarazzo, S., Del Zotto, M., and Zani, A. (2006). Gender and parental status affect the visual cortical response to infant facial expression. *Neuropsychologia* 44, 2987–2999. doi: 10.1016/j.neuropsychologia.2006.06.015

Proverbio, A. M., Matarazzo, S., Brignone, V., Del Zotto, M., and Zani, A. (2007). Processing valence and intensity of infant expressions: the roles of expertise and gender. *Scand. J. Psychol.* 48, 477–485. doi: 10.1111/j.1467-9450.2007.00616.x

Proverbio, A. M., Ornaghi, L., and Gabaro, V. (2018). How face blurring affects body language processing of static gestures in women and men. *Soc. Cogn. Affect. Neurosci.* 13, 590–603. doi: 10.1093/scan/nsy033

Repple, J., Habel, U., Wagels, L., Pawliczek, C. M., Schneider, F., and Kohn, N. (2018). Sex differences in the neural correlates of aggression. *Brain Struct. Funct.* 223, 4115–4124. doi: 10.1007/s00429-018-1739-5

Riva, P., Sacchi, S., Montali, L., and Frigerio, A. (2011). Gender effects in pain detection: speed and accuracy in decoding female and male pain expressions. *Eur. J. Pain* 15, 985.e1–985.e11. doi: 10.1016/j.ejpain.2011.02.006

Roberson, D., Kikutani, M., Döge, P., Whitaker, L., and Majid, A. (2012). Shades of emotion: what the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition* 125, 195–206.

Royet, J., Plailly, J., Delon-Martin, C., Kareken, D. A., and Segebarth, C. (2003). fMRI of emotional responses to odors: influence of hedonic valence and judgment, handedness, and gender. *Neuroimage* 20, 713–728. doi: 10.1016/S1053-8119(03)00388-4

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Rymarczyk, K., Żurawski, Ł, Jankowiak-Siuda, K., and Szatkowska, I. (2019). Empathy in facial mimicry of fear and disgust: simultaneous EMG-fMRI recordings during observation of static and dynamic facial expressions. *Front. Psychol.* 27:701. doi: 10.3389/fpsyg.2019.00701

Simon, D., Craig, K. D., Miltner, W. H., and Rainville, P. (2006). Brain responses to dynamic facial expressions of pain. *Pain* 126, 309–318. doi: 10.1016/j.pain.2006.08.033

Singh, L., Tan, A., and Quinn, P. C. (2021). Infants recognize words spoken through opaque masks but not through clear masks. *Dev. Sci.* [Epub ahead of print]. doi: 10.1111/desc.13117.

Smith, M. L., Cottrell, G. W., Gosselin, F., and Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychol. Sci.* 16, 184–189.

Sullivan, S., Campbell, A., Hutton, S. B., and Ruffman, T. (2017). What's good for the goose is not good for the gander: age and gender differences in scanning emotion faces. *J. Gerontol. B Psychol. Sci. Soc. Sci.* 72, 441–447.

Ugail, H., and Al-dahoud, A. A. (2019). Genuine smile is indeed in the eyes - the computer aided non-invasive analysis of the exact weight distribution of human smiles across the face. *Adv. Eng. Inf.* 42:100967.

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Yitzhak, N., Pertzov, Y., Guy, N., and Aviezer, H. (2020). Many ways to see your feelings: successful facial expression recognition occurs with diverse patterns of fixation distributions. *Emotion* [Epub ahead of print]. doi: 10.1037/emo0000812

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Face Mask Reduces the Effect of Proposer's (Un)Trustworthiness on Intertemporal and Risky Choices

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Previous literature suggested that individuals increase temporal and risk discounting at the presence of a proposer whose face is perceived as untrustworthy, suggesting the activation of protective choice patterns. By the way, the COVID-19 pandemic has substantially transformed the way we interact with other people, even bringing us into situations where the face of the person making a proposal is not fully visible, because of the mask. With the current study, we aimed at verifying if the effect of proposer's facial (un)trustworthiness on discounting behavior is modulated by mask wearing. In two different experiments, participants performed traditional delay and probability discounting tasks with masked proposers manipulated across trustworthiness levels. Results highlighted that, even after checking for subject-specific emotion recognition ability with masked faces, the presence of a masked untrustworthy proposer increases both delay and probability discounting parameters, although the effect is not statistically significant and smaller than the one detected at the presence of an untrustworthy proposer without a mask. These results suggest that the ability to perceive the proposer's (un)trustworthiness is affected by the mask, with a consequent less strong effect of proposer's (un) trustworthiness on choice behavior on both intertemporal and risky choices. Limits and possible implications are outlined and discussed.

Keywords: face mask, perceived trustworthiness, delay discounting, probability discounting, risk taking

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INTRODUCTION

Trustworthiness and Discounted Choices

In recent years, research on variables influencing decision-making started to devote more attention to the investigation of the role of social factors and actors in this domain. Particularly, when considering models of discounted decision-making, some evidence has been collected on the differences on decisional outcomes, due to decision-maker's individual propensity to trust others as well as on the role of proposer's perceived trustworthiness. In our everyday life, when faced with someone making a proposal and asking us for a choice between possible courses of action, visible features of the proposer can play a crucial role. Children, for example, have been shown to enhance their willingness to wait in order to get a more attractive reward, as assessed *via* traditional marshmallow test, when the person proposing the choice and delivering the incentive is regarded as trustworthy, as based on both, face appearance (Michaelson et al., 2013) and observed behavior during previous interactions (Michaelson and Munakata, 2016). Of relevance, effect of trustworthiness may act also without previous direct knowledge of proposer trustworthiness and by the means of reputational influence (e.g., Izuma, 2012; Ponsi et al., 2017; Bellucci and Park, 2020). Trust-based factors have been found to play a role in postponing gratification even when children had no knowledge about the individual providing the future reward (neither face nor behavior), since simply having a greater degree of generalized trust in people led children to wait longer (Ma et al., 2018). A possible explanation for this result with untrustworthy proposer has been linked to the waiting time typically included in temporal discounting protocols, such as that, as based on deliberative reasoning process, people tend to prefer immediate rewards as the delayed one is perceived as not surely obtainable in future, given the proposer's untrustworthiness. Also, others' perceived untrustworthiness can also feel like a danger, triggering unpleasant feelings that impact intertemporal and risk decisions (Harris, 2012; Koppel et al., 2017). By the way, in a recent paper on adult samples, it was not only reported that proposer's facial perceived untrustworthiness is associated with higher temporal discounting rate therefore indicating lower preference toward reward's postponing, but also that the same effect applies to subjects' probability discounting, for which participants were asked to choose between smaller sure and larger but risky options and were aware that reward delivery system was based on randomness (Anzani et al., 2022). This evidence indicating a lower propensity toward risk taking with untrustworthy proposers, even if in need of replication, seems to suggest the possibility that this effect of untrustworthiness on decision-making may be sustained by a more domain-independent and less deliberative underlying process than ever thought before. Despite specific mechanisms involved in this phenomenon, taken together, evidence accumulated in literature until now, seem to suggest a crucial role of proposer's (perceived) (un)trustworthiness in our everyday choice outcomes, particularly when considering face-to-face interactions.

Impact of Mask Wearing

The COVID-19 pandemic that hit the world in the 2020 has caused drastic changes in our usual habits both on personal (e.g., Cannito et al., 2022) and societal level (e.g., Ceccato et al., 2021). In order to contain the virus spread, several restraint measures have been introduced, such as avoiding direct contact with other people and wearing masks. While existing evidence suggest that some processes, such as social attention, are not significantly affected by mask wearing (e.g., Dalmaso et al., 2021), both reduction of interpersonal interaction and impossibility to access to the whole set of facial expressions have the potential to produce an influence on face-to-face interactions and to affect social relationships (e.g., Carbon, 2020). For instance, some studies already shown that wearing face mask reduces accuracy in emotion recognition and perceived closeness (Grundmann et al., 2021) and that this effect is even larger for individuals with autistic traits (Pazhoohi et al., 2021). Moreover, a reduction in accuracy when identifying emotions in masked vs. no-masked faces stimuli was also reported for a population, healthcare students, that is planned to be exposed to masked human faces in the next future (Bani et al., 2021) and across the lifespan with older adults (Schroeter et al., 2021), adults (e.g., Carbon, 2020), and children (Ruba and Pollak, 2020) experiencing the same effect. While generally agreeing on the phenomenon, existing results in literature highlight some differences for what concerns the expressed emotion. By way of illustration, some evidence report that this effect is present for all the basic tested emotions (e.g., Pazhoohi et al., 2021) while other report that this does not apply to some emotions, such as fear (e.g., Carbon, 2020) or for neutral expression (e.g., Marini et al., 2021). Furthermore, some evidence highlighted that the effect of mask wearing influences not only emotion recognition but also other face-induced perceived features, such as perceived trustworthiness. For example, it was recently shown that a masked face received significantly lower perceived trustworthiness evaluations as compared to the no-masked version (Gabrieli and Esposito, 2021). Similarly, in another work, authors reported a similar result also showing that reduced trustworthiness effect for masked stimuli was stronger for those participants who thought that mask had a poorer protecting capability and felt more burdened when wearing it (Biermann et al., 2021). Following this line of reasoning, it can be hypothesized that when faced with an (already) untrustworthy proposer wearing a mask, an augmented effect on decision-maker's discounting behavior should be detected (i.e., a higher shift toward immediate and sure options as compared to results reported by Anzani et al., 2022). On the other side, it was recently shown that wearing mask affects other perceived features, for example, it increases perceived attractiveness for both male and female stimuli (Hies and Lewis, 2022; Parada-Fernández et al., 2022). Therefore, as attractiveness have been reported to increase perceived trustworthiness (Pandey and Zayas, 2021) and trustworthiness have been proved to influence decision-making outcomes (e.g., Jaeger et al., 2019; Qi et al., 2021; Anzani et al., 2022), it can also be hypothesized that, through an indirect effect due to increased perceived attractiveness (already) untrustworthiness proposers are perceived as less untrustworthy and, therefore, a reduced effect on decision-maker's discounting behavior should be detected. To deeper explore this phenomenon and investigate whether the presence of surgical mask produce a change on the effect of proposer's trustworthiness on decision-making and to which extent, in the current work, we replicated the experimental procedure proposed by Anzani et al. (2022) and conducted two separate experiments (experiment A investigating delay discounting and experiment B investigating probability discounting) after manipulating proposer's stimuli to which a face surgical mask was applied.

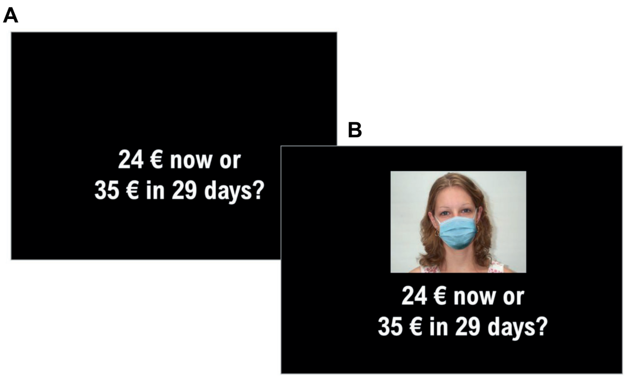

FIGURE 1 | Trial example in the "baseline" **(A)** and "proposer" block **(B)**.

MATERIALS AND METHODS

Sample

The sample was composed of 43 volunteers (19 male, mean age = 27.0, SD = 8.8 years) who performed the experimental procedure in experiment A and 45 volunteers (23 male, mean age = 20.1, SD = 1.9 years) who performed in experiment B. All participants were neurotypical and had no psychiatric or addiction history. We decided to screen participants with the characteristic as each of them has been proved to influence, in different ways, discounting behavior (e.g., Amlung et al., 2019; Mok et al., 2021). The experiment was performed online, with the platform E-primeGO (Psychology Software Tools, Inc. E-Prime Go; 2020).[1] All participants from both experiments received a link *via* email through which they were presented a request for informed consent to take part in the study, together with initial instructions about the tasks to be performed. Once they had given their consent, participants were directed to the experimental procedure. Data were collected during November 2020, with concomitant data gathering schedule for the two experiments, to avoid setting manipulation differences due to time of administration. Participants received no money or other form of compensation to take part in this study. The study complies with the Declaration of Helsinki and received approval from the reference Ethics Committee.

Behavioral Task

Before the task administration, participants were asked to answer a brief survey including demographic questions about some basic information, such as their age and gender, and clinical history as screening criteria. No participants were excluded as based on these questions. After recruiting, participants have been randomly assigned to experiment A (delay discounting) or to experiment B (probability discounting).

For both studies, participants were presented choice items from the Money Choice Questionnaire (MCQ, experiment A) or the Probability Discounting Questionnaire (PDQ, experiment B), which consisted of the standard delay and probability discounting questionnaires from Kirby et al. (1999) and Madden et al. (2009), respectively, in seven different blocks (1 baseline block and 6 "proposer" blocks). In the baseline block, participants were standardly presented the two choice options and asked to choose as quickly as possible using the keyboard, pressing "A" and "L" keys. For the MCQ, participants were asked to choose between smaller sooner option and larger delayed options, respectively. Half of the items required an inverted response system ("A" for larger and "L" for smaller) in order to avoid side bias. Same approach was employed for the PDQ at which participants were asked to choose between a smaller sure option and larger probabilistic one. For both task, participants were also presented choice items in "proposer" blocks, which provided a face stimulus and were asked to imagine that the showed face was the person proposing the choice between the two options while having no role in potential money delivery (see **Figure 1**). The used facial stimuli were manipulated for gender (male and female) and for perceived trustworthiness level (trustworthy, neutral, and untrustworthy) resulting in six different blocks (for a similar procedure, see Anzani et al., 2022). Order of presentation of the seven blocks was randomized as well as items' order within each block. In order to create the masked versions of the face stimuli in the proposer blocks, the original pictures from Minear and Park (2004) were edited with open-source graphical manipulation software GIMP (version 2.10.22). The mask was adapted to the best fit to each face, and colors and shadows were matched to ensure a realistic rendering of the pictures. Each item of the questionnaire was shown with all six masked proposers, so the whole experiment consisted in 27 (baseline) + 162 trials (proposer blocks) for the MCQ and 30 (baseline) + 180 trials (proposer blocks) for the PDQ. Also, for both studies, participants completed a second behavioral task investigating participants' ability to recognize emotions expressed by facial masked stimuli. To this purpose, a total of 36 stimuli were obtained from FACES database (Ebner et al., 2010). Selected stimuli varied across gender (male and female), age (young adult, adult, and elderly) and expressed emotion (neutral, sadness, happiness, disgust, fear, and anger). Then, a modified version of each stimulus was created by adding a fitted mask (see **Figure 2** for stimuli example). Stimulus editing was performed *via* GIMP (version 2.10.22). For both studies, half of participants performed emotion recognition task as first and discounting task (MCQ or PDQ) as second, while the other half performed the tasks in reverse order.

Data Pre-processing and Analysis

One participant who performed the MCQ (experiment A) and four participants who performed the PDQ (experiment B) were discarded from subsequent analysis because their data were indistinguishable from random choices. To determine this, we compared the percentage of correct answers to the emotion recognition task of each participant and considered random responders those who had an accuracy comparable to random chance (1 over 6 = 16%). Therefore, the final sample was composed of 42 participants for experiment A and 41 participants for experiment B. Data pre-processing and statistical analysis were carried out using R. Computation of discounting parameters

[1]https://support.pstnet.com/

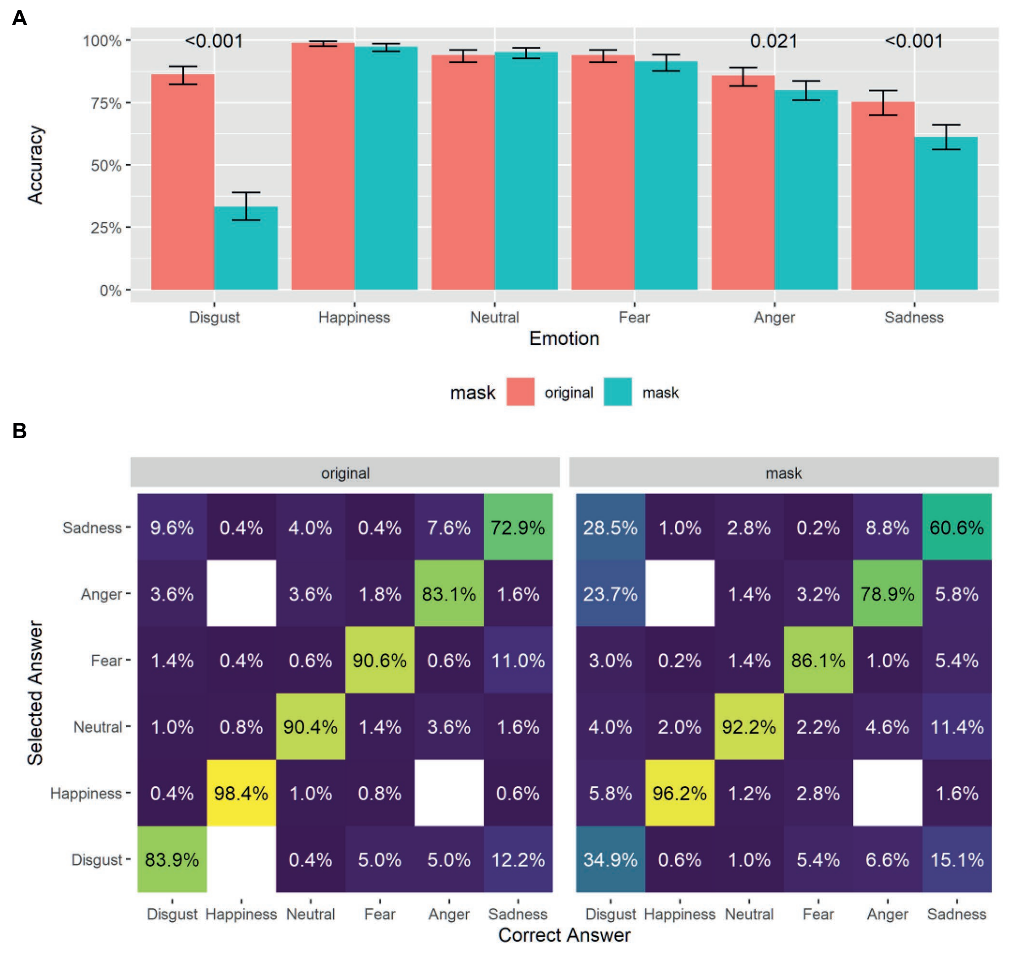

FIGURE 2 | (A) Emotion recognition accuracy across emotions and stimuli conditions. **(B)** Confusion matrix on emotion recognition.

for both tasks and for each block was based on the R syntax developed by Gray et al. (2016). Starting from participants' observed preferences, the syntax allows to calculate the discounting parameters (k and h) by assigning the most coherent parameter taking it from a pre-compiled list based on the hyperbolic discounting models (Mazur, 1987). The parameters come from the following two equations, where V is the subjective value of the reward A after a delay T:

$$V = \frac{A}{1 + kT} \tag{1}$$

or with odds against winning $\Theta = (1 - p)/p$ where p is the probability shown with the uncertain option:

$$V = \frac{A}{1 + h\Theta} \tag{2}$$

Obtained discounting parameters were then log-transformed to ensure normality as based on literature (e.g., Calluso et al., 2020; Cannito et al., 2021; Iodice et al., 2022).

Together with explicit preferences during the task, participants' response times (RTs) in milliseconds (ms) were also collected. RTs data cleaning was performed by removing upper outliers at three standard deviations (SD) and excluding trial shorter than 250 ms. RTs were then re-scaled in seconds (s) to help with convergence of the mixed models used in the analysis.

All the analysis were carried out using mixed effects models with the *lme4* R package (Bates et al., 2015), omnibus tests were obtained with the *Anova* function from the *car* package (Fox and Weisberg, 2019), and *post-hoc* comparison and estimated marginal means were computed with the *emmeans* package (Lenth, 2021).

RESULTS – EMOTION RECOGNITION TASK

As the effect of mask on discounting task may have been influenced by subject-specific ability to read facial cues from masked faces, participants' ability to accurately recognize emotion as expressed by a masked face was assessed. A general linear mixed model was performed to test the effect of mask (mask and normal), of emotion (neutral, happiness, disgust, fear, anger, and sadness) and task (td and pd) on accuracy performance. Results highlighted no effect of task, but significant effect of mask, emotion, and interaction effect between the two (see **Table 1**; **Figure 2A**) with disgust ($p < 0.001$), sadness stimuli ($p < 0.001$), and anger stimuli ($p = 0.02$) showing a statistically significant difference in accuracy between mask and normal stimuli. We then conducted a more exploratory, qualitative error analysis using a confusion matrix, a double-entry table in which the columns indicate the expected (correct) responses, and the rows indicate the responses given by the participant. In this format, correct responses are placed along the diagonal of the matrix, and the other cells in each column indicate how the incorrect responses are distributed for each stimulus. In fact, the percentages reported are calculated per column (**Figure 2B**). The confusion matrix seems to suggest that, also with the original no masked stimuli, there was some confusion between expressions of disgust, sadness an anger, and that this confusion is greatly amplified with mask stimuli. After exploring participants' performance on emotion recognition task across conditions, to test the possible role of subject-specific ability to recognize masked emotions on discounting behavior with (un)trustworthy masked proposers, participants' random slope with mask stimuli in the emotion recognition task was entered in the following analyses on the effect of masked proposers with different levels of trustworthiness on delay (experiment A) and probability discounting (experiment B).

TABLE 1 | Omnibus test for effects of mask, emotion, and task on emotion recognition accuracy.

	χ^2	DF	p
(Intercept)	**660.03**	1	**<0.001**
Mask	**40.94**	1	**<0.001**
Emotion	**326.65**	5	**<0.001**
Task	0.19	1	0.664
Mask: emotion	**140.63**	5	**<0.001**

Significant effects are reported in bold.

Results Experiment A

Delay Discounting

Following previous literature (e.g., Calluso et al., 2019), delay discounting parameter k were log-transformed to address normality. To test for the effect of the proposer on delay discounting parameter's change compared to baseline, we used a linear mixed effect model, with the current proposer as predictor of the log-transformed k value, and with a random intercept for each participant, accounting for individual differences and for the repeated measures design. The full code for all the models is available in the online repository. The model uses treatment coding for factors, with the baseline set as the reference value, so each coefficient of the model can be used to test the change in k due to each proposer. We apply the t as z criterion for significance of the coefficients, so t values higher than 2 can be considered significant. Even though this method has been shown to be anti-conservative, this mostly apply to smaller sample sizes (Luke, 2017). Results are reported in **Table 2**. Both male and female untrustworthy proposers and also the male neutral proposer elicit a significant increase in discounting rate compared to the baseline, indicating participants' reduced availability to wait in order to obtain a larger reward (**Figure 3A**).

To test the different contributions of the proposer's features, we used a second mixed effect model with gender and trustworthiness of the proposer as fixed factors and a random intercept for each subject and excluding the data coming from the baseline condition (for which the tested factors are meaningless). Proper omnibus tests for main effects and interactions were obtained by setting contrasts as sum contrasts (Singmann and Kellen, 2019). Results of omnibus tests (type 3, Wald χ^2 tests) revealed that neither gender nor the level of trustworthiness of the proposer had a significant effect on the rate at which participants discount delayed options (see **Supplementary Table S1**; **Figure 3B**).

Response Times

For each subject only RTs higher than 250 ms and lower than three standard deviations over the mean were computed for that subject. The same generalized mixed effect model was employed to investigate response times (RTs). We set the family of the distribution to inverse Gaussian and coded the model

TABLE 2 | Fixed effects of proposers compared to baseline.

Term	Estimate	SE	Statistic	CI 95%	
				LL	UL
(Intercept)	−3.936	0.204	**−19.277**	−4.336	−3.536
Proposer FT	0.165	0.179	0.920	−0.186	0.515
Proposer MT	0.310	0.179	1.732	−0.041	0.661
Proposer FN	0.170	0.179	0.951	−0.181	0.521
Proposer MN	0.437	0.179	**2.444**	0.087	0.788
Proposer FU	0.671	0.179	**3.748**	0.320	1.021
Proposer MU	0.594	0.179	**3.321**	0.244	0.945

FT, female trustworthy; MT, male trustworthy; FN, female neutral; MN, male neutral; FU, female untrustworthy; MU, male untrustworthy; CI, confidence interval, LL, lower level; UL, upper level. Same labels are valid for all the subsequent tables. Significant effects are reported in bold.

with current proposer as fixed effect, and with a random intercept and slope for each subject (see **Table 3**). Results highlighted that all proposer conditions elicited mean RTs significantly faster than the baseline condition (**Figure 4A**).

We tested the effects of gender, level of trustworthiness and given response using the second generalized mixed effects model. Omnibus Wald tests show that the main effect of response is significant, participants were faster when expressing a preference for the immediate option (see **Table 4**). The two-way interaction between level of trustworthiness and given response is significant and looking at *post-hoc* comparisons we can see that the difference in response times between immediate and delayed options holds with trustworthy and untrustworthy proposers but is less stronger for neutral proposers (see **Table 5**; **Figure 4B**).

The Impact of Emotion Recognition Ability on *k* Parameter

As anticipated, for the analyses on the effect of proposers on discounting rate, we wanted to investigate whether participants' general ability to correctly recognize emotions when faces are masked and not masked, may have an influence on the effect produced by proposers' (un)trustworthiness. The basic idea was that these participants might be able to gather facial information more efficiently than other when the stimulus was masked. To obtain this indicator, two possible measures were taken into consideration. The first was the difference in accuracy between the masked and unmasked conditions while, the second option was to take advantage of our GLMM on emotion recognition accuracy, which was specified with a random slope for the effect of mask for each participant. This means that for each subject, the model computes an estimate for the difference in accuracy in the masked and unmasked conditions. While these two measures are highly correlated ($r = 0.814$, $p < 0.001$), we opted for the second one because it showed a better continuous normal distribution, and it was computed within a model that considers the difficulty of different emotions. As first, we tested the role of this variable on discounting parameter *k* by reperforming the same mixed effect model, to the log-transformed *k* discounting parameter with current proposer as fixed effect and a random intercept for each subject. Using the same *t* as z criterion for significance we find similar results that is both masked untrustworthy proposer and the masked male neutral proposer elicit a significant increase in discounting rate. If we look at the back-transformed estimated values of the k parameters, we can see that although significant, the size of these effects is smaller and the increase from the baseline is much less evident (see **Supplementary Table S3**; **Supplementary Figure S1A**).

Furthermore, we also conducted the second mixed effect model for *k* parameters on the proposer conditions (without baseline), with gender and trustworthiness as fixed effects (see **Supplementary Table S4**). As for previous model, Omnibus Wald chi-square tests revealed no effect of emotion recognition ability, and that neither gender nor the level of trustworthiness of the proposer have a significant effect on the rate at which participants discount delayed options (**Supplementary Figure S1B**).

The Impact of Emotion Recognition Ability on Response Times

We used the same generalized mixed effect model for response times. We set the family of the distribution to inverse Gaussian and we coded the model with current proposer as fixed effect, and with a random intercept and slope for each subject. Again, similarly to study 1, we find that all proposer conditions are significantly faster than the baseline condition, but emotion recognition ability effect was not significant. A significant interaction was detected when considering emotion recognition ability with male trustworthy proposer and with male untrustworthy proposer (see **Supplementary Table S5**).

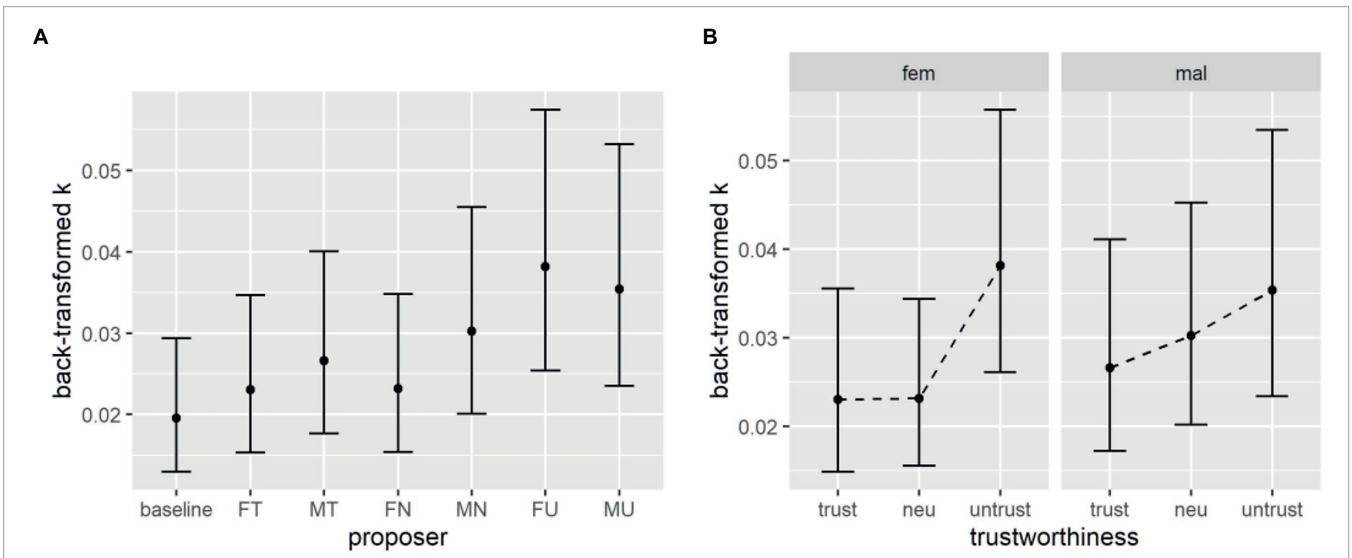

FIGURE 3 | Discounting parameters back-transformed from the log space. **(A)** Parameter estimates from the first model. (**B)** Parameter estimates from the second model without the baseline.

We then plotted response times across condition (see **Supplementary Figure S1C**) with 5 levels of emotion recognition ability (at 10th, 25th, 50th, 75th, and 90th percentiles).

Finally, we retest effects of gender, level of trustworthiness and given response after including emotion recognition ability. Omnibus Wald tests showed a significant effect of emotion recognition ability and its interaction with the condition (see **Supplementary Tables S6A**, **S6B**). Again, we plotted response times across proposers' trustworthiness levels with different level of emotion (**Supplementary Figure S1D**).

Results Experiment B

Probability Discounting

Similarly to delay discounting data, a mixed effects model on log-transformed *h* parameters, with current proposer as fixed effect and a random intercept for each subject, with the baseline condition as reference level, was performed. Using the *t* as z criterion, results revealed that the untrustworthy proposers again elicited a higher discounting rate h compared to baseline. Also, the male neutral proposer is not different from baseline, while the female neutral and the male trustworthy proposers laid around the significance threshold of $t>2$ (**Table 6**; **Figure 5A**).

Looking at the second mixed effect model on discounting parameters, Wald tests showed that the interaction between gender and trustworthiness level was at the edge of significance. Indeed, pairwise comparisons for the three levels of trustworthiness indicated no significant difference (see **Supplementary Table S2**). The only significant difference was detected between the trustworthy and untrustworthy female proposers (see **Table 7**; **Figure 6B**).

Response Times

A generalized mixed effect model was performed to the analysis for response times in the probability discounting task, comparing the proposer conditions to the baseline. All coefficients are negative and significant (**Table 8**), and the estimated marginal means revealed that the baseline condition elicited indeed slower responses (**Figure 6A**).

Looking into the differences within the proposer conditions, the second generalized mixed effect model's results revealed that the only significant effect is the given response. In particular, participants were slightly faster when choosing the smaller certain option rather than the larger probabilistic one (**Table 9**; **Figure 7B**). No other main nor interaction effects were found to be significant.

The Role of Emotion Recognition Ability on *h* Parameter

We reperformed the mixed effects model on log-transformed *h* parameters, with current proposer as fixed effect and a random intercept for each subject, with the baseline condition as reference level, and including the participants' random slope

TABLE 3 | Fixed effects of proposers compared to baseline on RTs in the delay discounting task.

Term	Estimate	SE	Statistic	CI 95% LL	CI 95% UL
(Intercept)	2.990	0.102	**29.233**	2.789	3.190
Proposer FT	−0.723	0.104	**−6.953**	−0.926	−0.519
Proposer MT	−0.758	0.108	**−7.009**	−0.970	−0.546
Proposer FN	−0.629	0.099	**−6.333**	−0.824	−0.435
Proposer MN	−0.697	0.101	**−6.922**	−0.895	−0.500
Proposer FU	−0.733	0.096	**−7.615**	−0.922	−0.544
Proposer MU	−0.685	0.107	**−6.400**	−0.894	−0.475

Significant results are in bold.

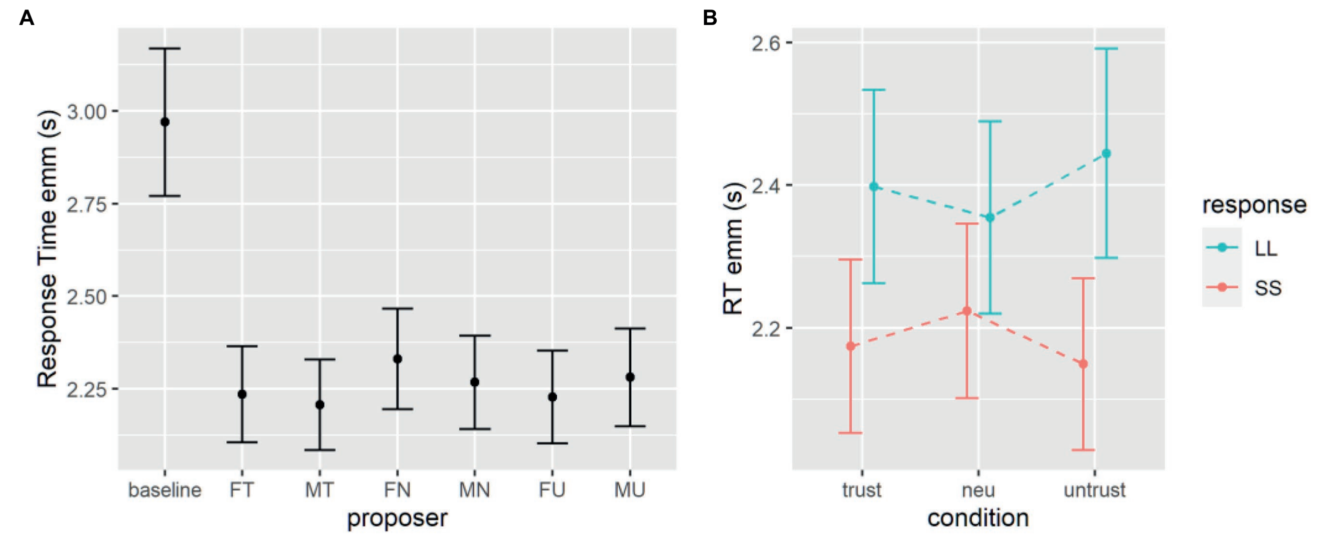

FIGURE 4 | Estimates for response times in the delay discounting task with masked proposers. **(A)** Estimates from the first model, with baseline data. **(B)** Estimates from the second model, without the baseline data. SS, smaller sooner option; LL, larger later option.

TABLE 4 | Omnibus test of effects for gender, trustworthiness and given response on RTs.

	χ^2	DF	*p*
(Intercept)	**1,482.72**	1	**<0.001**
Gender	0.10	1	0.752
Trustworthiness level	0.03	2	0.985
Response	**61.08**	1	**<0.001**
Gender: trustworthiness level	3.42	2	0.181
Gender: response	0.20	1	0.652
Trustworthiness level: response	**6.63**	2	**0.036**
Gender: trustworthiness level: response	0.48	2	0.785

Significant results are in bold.

TABLE 5 | *Post-hoc* comparison of RTs between given response within each level of trustworthiness.

Response contrast	Proposer	Estimate	SE	*p*
SS – LL	Trustworthy	−0.229	0.046	**<0.001**
SS – LL	Neutral	−0.131	0.046	**0.004**
SS – LL	Untrustworthy	−0.309	0.054	**<0.001**

SS, smaller sooner option; LL, larger later option.
Significant results are in bold.

TABLE 6 | Fixed effects of proposer on probability discounting compared to baseline.

Term	Estimate	SE	Statistic	CI 95%	
				LL	UL
(Intercept)	1.222	0.129	**9.447**	0.969	1.476
Proposer FT	0.036	0.077	0.467	−0.115	0.188
Proposer MT	0.152	0.077	1.965	0.000	0.303
Proposer FN	0.157	0.077	**2.031**	0.006	0.309
Proposer MN	0.040	0.077	0.512	−0.112	0.191
Proposer FU	0.244	0.077	**3.161**	0.093	0.396
Proposer MU	0.164	0.077	**2.124**	0.013	0.316

Significant results are in bold.

for emotion recognition ability with mask stimuli. As for effect on *k* parameters, we found no significant differences in the model outcomes after including emotion recognition ability (**Supplementary Table S7**).

Looking at the second mixed effect model on discounting parameters, Wald tests show that the interaction between gender and trustworthiness is now at the edge of significance (**Supplementary Table S8**). Indeed, pairwise comparisons for the three levels of trustworthiness show no significant difference. The only significant difference is between the trustworthy and untrustworthy female proposers ($t = -2.74$, $p = 0.02$). No effect of emotion recognition ability was detected.

The Role of Emotion Recognition Ability on Response Times

We repeated the analysis for response times in the probability discounting task, comparing the proposer conditions to the baseline with a generalized mixed effect model. All coefficients are negative and significant, and we can see from the estimated marginal means that the baseline condition is indeed still slower. As for h parameters, no main effect of emotion recognition ability neither interaction was highlighted (see **Supplementary Table S9**).

Looking into the differences within the proposer conditions, with the second generalized mixed effect model, we see that the only significant effect is the given response, in particular participants are slightly faster when choosing the certain option. We can also observe that no main neither interaction effect with emotion recognition ability were detected (see **Supplementary Table S10**).

DISCUSSION

In previous study, Anzani et al. (2022) reported that, when faced with an untrustworthy proposer during intertemporal and risky choice, participants modify their discounting behavior by increasing preference toward immediate and sure alternatives, thus showing a more protective choice pattern. In this study we replicated the same paradigm, trying to verify if face masks used as a safety measure against COVID-19 could influence the proposer's perceived trustworthiness and, therefore, it modulates the impact of proposer's perceived trustworthiness on participants' decision-making outcomes. In particular, as based on existing evidence, which suggests that wearing a mask reduces perceived trustworthiness (Biermann et al., 2021; Gabrieli and Esposito, 2021), we may expect that the presence of the mask would let participants to perceive untrustworthy proposers as even more untrustworthy, thus amplifying the effect of proposers' untrustworthiness on discounting behavior. On the other side, in a more indirect way, as literature suggested that wearing a mask increases perceived trustworthiness (Pandey and Zayas, 2021), we could also expect that the presence of the mask produces an increase in perceived trustworthiness for untrustworthy proposers, thus reducing the effect of proposers' untrustworthiness on discounting behavior. To address this issue, we first looked at the differences in the discounting parameters between the baseline and the masked proposer conditions. In the delay discounting task (experiment A), untrustworthy proposers and the male neutral proposer still induced a steeper discounting compared to the baseline, but the effect is smaller when compared to the previous study with proposers' faces full visible (Anzani et al., 2022). In the probability discounting task (experiment B), results were more surprising: even the male trustworthy masked proposer induced a higher discounting rate compared to the baseline even if the effect is not significant. In general, the estimated discounting parameters in all the seven conditions appears to be more similar to each other, also because the baseline discounting parameter appears to be higher than what reported previously (Anzani et al., 2022). Looking into the effects of the proposer's gender and level of trustworthiness for the delay discounting task, we found no significant effect, even if plot of estimates for each condition revealed a similar pattern to what observed in Anzani et al. (2022). For the probability

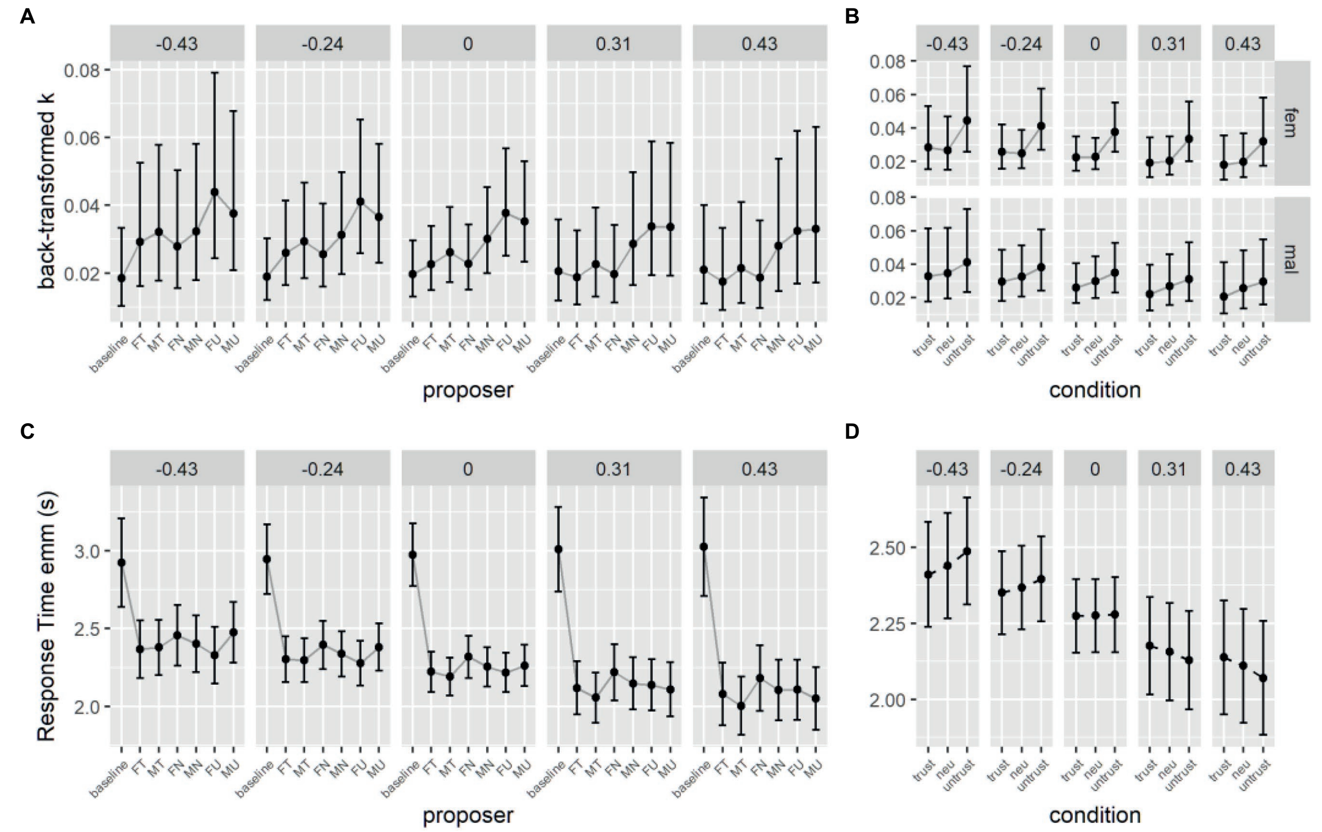

FIGURE 5 | (A) Parameter estimates from the first model and (**B**) parameter estimates from the second model without the baseline after including emotion recognition ability. **(C)** Response times across conditions at various levels of emotion recognition ability. **(D)** Response times across proposers' trustworthiness levels at various levels of emotion recognition ability.

TABLE 7 | *Post-hoc* comparison on log(h) between levels of trustworthiness for female and male proposers.

Contrast	Gender	Estimate	SE	DF	Statistic	*p*
Trustworthy – neutral	Female	−0.121	0.066	107	−1.822	0.214
Trustworthy **–** untrustworthy	Female	−0.208	0.076	88	**−2.745**	**0.022**
Neutral – untrustworthy	Female	−0.087	0.075	89	−1.164	0.743
Trustworthy – neutral	Male	0.112	0.066	107	1.692	0.281
Trustworthy – untrustworthy	Male	−0.012	0.076	88	−0.162	>0.999
Neutral – untrustworthy	Male	−0.125	0.075	89	−1.661	0.300

Significant results are in bold.

discounting task, a main effect of level of trustworthiness and the interaction between gender and trustworthiness were detected, both at the very edge of significance. Looking at the *post-hoc* comparisons and at the parameter estimates, results seem to suggest that only with the female proposers, the h parameter with untrustworthy proposers is significantly higher than with the trustworthy ones, while all other comparisons were not significant. Compared to discounting rates, results on response times analysis revealed a more similar patter to what reported by Anzani et al. (2022). Still, in the baseline condition participants took more time to decide compared to the masked proposer conditions, and these differences appear to be even more pronounced. Looking at the differences within the proposer conditions, the only effect that we find is still the final choice (given response), meaning that uncertain and delayed options require more time to decide, and the level of trustworthiness has little to no effect.

Results are quite the same when participant's ability to recognize emotions from a face with mask is added to the tested models. Interestingly, the only significant effects (main or interaction with trustworthiness level) for the emotion recognition ability have been detected within experiment A (for *k* parameters and response times in delay discounting task) but those effects are not present for dependent variables in experiment B.

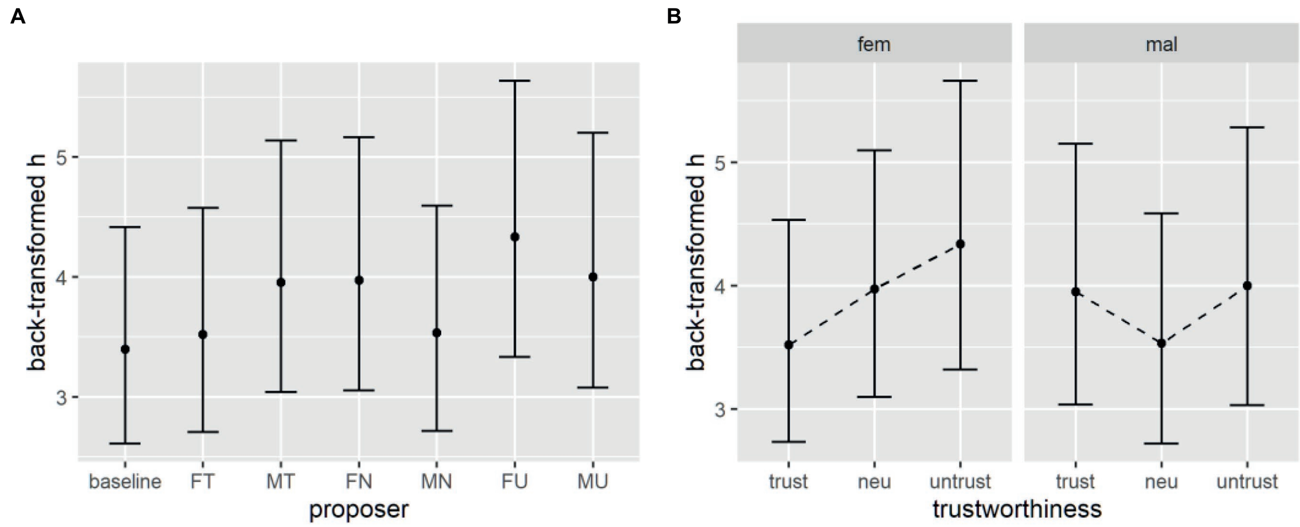

FIGURE 6 | Probability discounting parameters, back-transformed from the log space. **(A)** Parameter estimates from the first model. **(B)** Parameter estimates from the second model without the baseline.

TABLE 8 | Fixed effects of proposer compared to baseline on RTs in the probability discounting task.

Term	Estimate	SE	Statistic	CI 95%	
				LL	UL
(Intercept)	2.691	0.114	**23.636**	2.467	2.914
Proposer FT	−0.891	0.090	**−9.889**	−1.067	−0.714
Proposer MT	−1.031	0.090	**−11.521**	−1.207	−0.856
Proposer FN	−0.942	0.087	**−10.804**	−1.113	−0.771
Proposer MN	−1.005	0.089	**−11.313**	−1.179	−0.831
Proposer FU	−0.975	0.093	**−10.442**	−1.158	−0.792
Proposer MU	−0.954	0.097	**−9.887**	−1.144	−0.765

Significant results are in bold.

TABLE 9 | Omnibus test for effects of gender, trustworthiness level, and response on RTs.

	χ^2	DF	*p*
(Intercept)	**612.10**	1	**<0.001**
Gender	1.23	1	0.267
Trustworthiness level	0.51	2	0.777
Response	**8.96**	1	**0.003**
Gender: trustworthiness level	4.87	2	0.088
Gender: response	0.09	1	0.765
Trustworthiness level: response	2.09	2	0.351
Gender: trustworthiness level: response	0.59	2	0.745

Significant results are in bold.

We consider these results to be in line with two possible explanations. As a first possibility, as face mask covers part of the proposer's face that was a source of information in the evaluation process of their (un)trustworthiness, participants may have perceived untrustworthy faces as less untrustworthy and trustworthy faces as less trustworthy, thus producing an approximation between the effects of the two conditions. As second, due to an increase in perceived attractiveness and to a consequent increase in perceived trustworthiness, untrustworthy proposers may have been perceived as less untrustworthy. This conclusion would also been supported by evidence reporting that, in first impression creation with not masked faces, facial attractiveness evaluation precedes trustworthiness evaluation (Gutierrez-Garcia et al., 2019). This second explanation, by the way, would not justify why, in the current study, trustworthy masked proposers were possibly perceived as less trustworthy given that, in some cases, compared to results reported by Anzani et al. (2022), they produced effects that are more in line with untrustworthy proposers' effect.

At last, when considering results on masked emotion recognition ability itself, our results seem to be in line with previously reported findings, particularly for what concerns the extremely lower accuracy on masked disgusted stimuli compared to other masked emotions (e.g., Carbon et al., 2022).

CONCLUSION

Nevertheless, our conclusion may have been impacted by some methodological limits. First of all, perceived trustworthiness (trustworthy, neutral, and untrustworthy) of stimuli used as proposers was not directly evaluated by participants in this study but they were extracted from a validated database. Therefore, it was not possible to ascertain that each stimulus was indeed perceived as expected by the current sample. As second, a measure of perceived

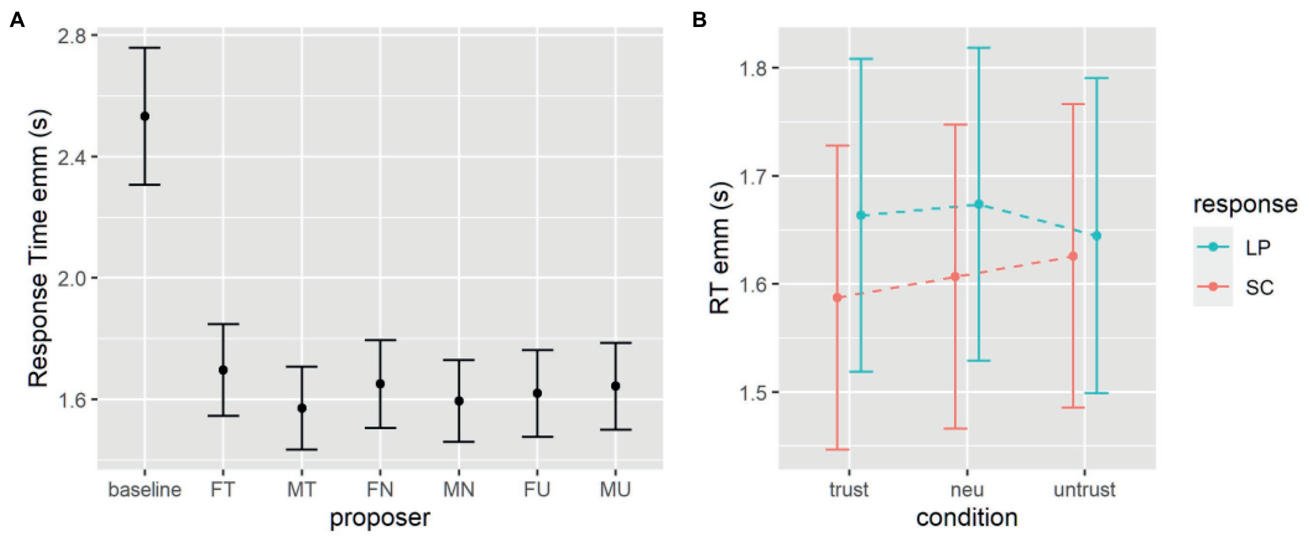

FIGURE 7 | Estimates for response times in the probability discounting task. **(A)** Estimates from the first model, where the baseline is the condition with the highest RTs. **(B)** Estimates from the second model, without the baseline data. SC, small certain option; LP, later probabilistic option.

attractiveness for each presented stimulus, may have helped in disentangle the effect induced by adding a mask on proposer's face. As third relevant limit, it would have been useful to include a measure of participants' perception and/or beliefs about the role of mask wearing in social perception of trustworthiness as this, in addition to the occlusion of physical facial cues, may have produced the highlighted effects. Nonetheless, participants' history with COVID-19 (both from personal and vicarious perspective) may have an influence on masked face perception and should, therefore, taken into account in future studies. Furthermore, as a general consideration to better evaluate the role of mask, it may be useful for future studies to replicate data collection by applying a within subject design for stimulus typology (with mask and without mask) as well as to include eye movements recording to help deepening our understanding of the perceptual dynamic that may contribute to discounting preferences' change and the participant's body state during emotion recognition task given evidence suggesting its contribution, particularly when considering disgust stimuli (e.g., Pezzulo et al., 2018). At last, as future direction, it would be particularly useful to replicate the experimental protocol by controlling for ethnic matching between face stimuli and the respondent as well as with elderly participants given the well-known positivity effect (e.g., Di Domenico et al., 2015) that may affect their ability to perceive facial (un)trustworthiness (e.g., Chen et al., 2021) as well as because they represent a risk population for fraud (Burnes et al., 2017).

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/qu8fg/view_only=d2307c78bbd64b4ea782f822f3314a43.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of Psychology (IRBP) of the Department of Psychological, Health and Territorial Sciences at G. d Annunzio University of Chieti-Pescara. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LC conceived the experiment. SA and AB prepared tasks and conducted the experiment. LC and SA performed statistical analysis, figure generation, and prepared the draft manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.926520/full#supplementary-material

REFERENCES

Amlung, M., Marsden, E., Holshausen, K., Morris, V., Patel, H., Vedelago, L., et al. (2019). Delay discounting as a Transdiagnostic process in psychiatric disorders. *JAMA Psychiat.* 76, 1176–1186. doi: 10.1001/jamapsychiatry.2019.2102

Anzani, S., Cannito, L., Bellia, F., Di Domenico, A., Dell'Osso, B., Palumbo, R., et al. (2022). OXTR gene DNA methylation levels are associated with discounting behavior with untrustworthy proposers. *Brain Sci.* 12:98. doi: 10.3390/brainsci12010098

Bani, M., Russo, S., Ardenghi, S., Rampoldi, G., Wickline, V., Nowicki, S., et al. (2021). Behind the mask: emotion recognition in healthcare students. *Med. Sci. Educ.* 31, 1273–1277. doi: 10.1007/s40670-021-01317-8

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67. doi: 10.18637/jss.v067.i01

Bellucci, G., and Park, S. Q. (2020). Honesty biases trustworthiness impressions. *J. Exp. Psychol. Gen.* 149, 1567–1586. doi: 10.1037/xge0000730

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: An experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Burnes, D., Henderson, C. R., Sheppard, C., Zhao, R., Pillemer, K., and Lachs, M. S. (2017). Prevalence of financial fraud and scams among older adults in the United States: a systematic review and meta-analysis. *Am. J. Public Health* 107, e13–e21. doi: 10.2105/AJPH.2017.303821

Calluso, C., Tosoni, A., Cannito, L., and Committeri, G. (2019). Concreteness and emotional valence of episodic future thinking (EFT) independently affect the dynamics of intertemporal decisions. *PLoS One* 14:e0217224. doi: 10.1371/journal.pone.0217224

Calluso, C., Pettorruso, M., Tosoni, A., Carenti, M. L., Cannito, L., Martinotti, G., et al. (2020). Cognitive dynamics of intertemporal choice in gambling disorder. *Addict. Behav.* 109:106463. doi: 10.1016/j.addbeh.2020.106463

Cannito, L., Anzani, S., Bortolotti, A., Palumbo, R., Ceccato, I., Di Crosta, A., et al. (2021). Temporal discounting of money and face masks During the COVID-19 pandemic: the role of hoarding level. *Front. Psychol.* 12:642102. doi: 10.3389/fpsyg.2021.642102

Cannito, L., Annunzi, E., Viganò, C., Dell'Osso, B., Vismara, M., Sacco, P. L., et al. (2022). The role of stress and cognitive absorption in predicting social network addiction. *Brain Sci.* 12:643. doi: 10.3390/brainsci12050643

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C.-C., Held, M. J., and Schütz, A. (2022). Reading emotions in faces with and without masks is relatively independent of extended exposure and individual difference variables. *Front. Psychol.* 13:856971. doi: 10.3389/fpsyg.2022.856971

Ceccato, I., Di Crosta, A., La Malva, P., Cannito, L., Mammarella, N., Palumbo, R., et al. (2021). Public opinion in vaccine allocation priority: who comes first? *Psychol. Health* 1–21, 1–21. doi: 10.1080/08870446.2021.2007914

Chen, C., Xu, Y., Sun, Y., and Zhang, X. (2021). Age differences in facial trustworthiness perception are diminished by affective processing. *Eur. J. Ageing*, 1–10. doi: 10.1007/s10433-021-00643-5

Dalmaso, M., Zhang, X., Galfano, G., and Castelli, L. (2021). Face masks do not Alter gaze cueing of attention: evidence From the COVID-19 pandemic. *Iperception* 12:204166952110584. doi: 10.1177/20416695211058480

Di Domenico, A., Palumbo, R., Mammarella, N., and Fairfield, B. (2015). Aging and emotional expressions: is there a positivity bias during dynamic emotion recognition? *Front. Psychol.* 6:1130. doi: 10.3389/fpsyg.2015.01130

Ebner, N. C., Riediger, M., and Lindenberger, U. (2010). FACES—a database of facial expressions in young, middle-aged, and older women and men: development and validation. *Behav. Res. Methods* 42, 351–362. doi: 10.3758/BRM.42.1.351

Fox, J., and Weisberg, S. (2019). *An {R} Companion to Applied Regression* (*3rd Edn.*). Thousand Oaks, CA: Sage Publications.

Gabrieli, G., and Esposito, G. (2021). Reduced perceived trustworthiness during face mask wearing. *Eur. J. Investig. Health Psychol. Educ. (Online)* 11, 1474–1484. doi: 10.3390/ejihpe11040105

Gray, J. C., Amlung, M. T., Palmer, A. A., and MacKillop, J. (2016). Syntax for calculation of discounting indices from the monetary choice questionnaire and probability discounting questionnaire. *Journal of the experimental analysis of behavior* 106 156–163.

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Gutierrez-Garcia, A., Beltran, D., and Calvo, M. G. (2019). Facial attractiveness impressions precede trustworthiness inferences: lower detection thresholds and faster decision latencies. *Cognit. Emot.* 33, 378–385. doi: 10.1080/02699931.2018.1444583

Harris, C. R. (2012). Feelings of dread and intertemporal choice. *J. Behav. Decis. Mak.* 25, 13–28. doi: 10.1002/bdm.709

Hies, O., and Lewis, M. B. (2022). Beyond the beauty of occlusion: medical masks increase facial attractiveness more than other face coverings. *Cogn. Res. Princ. Implic.* 7, 1. doi: 10.1186/s41235-021-00351-9

Iodice, P., Cannito, L., Chaigneau, A., and Palumbo, R. (2022). Learned self-regulation in top-level managers through neurobiofeedback training improves decision making under stress. *Sci. Rep.* 12:6127. doi: 10.1038/s41598-022-10142-x

Izuma, K. (2012). The social neuroscience of reputation. *Neurosci. Res.* 72, 283–288. doi: 10.1016/j.neures.2012.01.003

Jaeger, B., Evans, A. M., Stel, M., and van Beest, I. (2019). Explaining the persistent influence of facial cues in social decision-making. *J. Exp. Psychol. Gen.* 148, 1008–1021. doi: 10.1037/xge0000591

Kirby, K. N., Petry, N. M., and Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *J. Exp. Psychol. Gen.* 128, 78–87. doi: 10.1037//0096-3445.128.1.78

Koppel, L., Andersson, D., Morrison, I., Posadzy, K., Västfjäll, D., and Tinghög, G. (2017). The effect of acute pain on risky and intertemporal choice. *Exp. Econ.* 20, 878–893. doi: 10.1007/s10683-017-9515-6

Lenth, R. V. (2021). Estimated marginal means, aka least-squares means [R Package Emmeans Version 1.6. 0]. Comprehensive R Archive Network (CRAN).

Luke, S. G. (2017). Evaluating significance in linear mixed-effects models in R. *Behav. Res. Methods* 49, 1494–1502. doi: 10.3758/s13428-016-0809-y

Ma, F., Chen, B., Xu, F., Lee, K., and Heyman, G. D. (2018). Generalized trust predicts young children's willingness to delay gratification. *J. Exp. Child Psychol.* 169, 118–125. doi: 10.1016/j.jecp.2017.12.015

Madden, G. J., Petry, N. M., and Johnson, P. S. (2009). Pathological gamblers discount probabilistic rewards less steeply than matched controls. *Exp. Clin. Psychopharmacol.* 17, 283–290. doi: 10.1037/a0016806

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Mazur, J. E. (1987). "An adjusting procedure for studying delayed reinforcement," in *The effect of delay and of intervening events on reinforcement value*. eds. M. L. Commons, J. E. Mazur, J. A. Nevin and H. Rachlin (New York: Lawrence Erlbaum Associates), 55–73.

Michaelson, L., de la Vega, A., Chatham, C. H., and Munakata, Y. (2013). Delaying gratification depends on social trust. *Front. Psychol.* 4:355. doi: 10.3389/fpsyg.2013.00355

Michaelson, L. E., and Munakata, Y. (2016). Trust matters: seeing how an adult treats another person influences preschoolers' willingness to delay gratification. *Dev. Sci.* 19, 1011–1019. doi: 10.1111/desc.12388

Minear, M., and Park, D. C. (2004). A lifespan database of adult facial stimuli. *Behav. Res. Methods Instrum. Comput.* 36, 630–633. doi: 10.3758/BF03206543

Mok, J. N. Y., Green, L., Myerson, J., Kwan, D., Kurczek, J., Ciaramelli, E., et al. (2021). Does ventromedial prefrontal cortex damage really increase impulsiveness? Delay and probability discounting in patients with focal lesions. *J. Cogn. Neurosci.* 33, 1909–1927. doi: 10.1162/jocn_a_01721

Pandey, G., and Zayas, V. (2021). What is a face worth? Facial attractiveness biases experience-based monetary decision-making. *Br. J. Psychol.* 112, 934–963. doi: 10.1111/bjop.12495

Parada-Fernández, P., Herrero-Fernández, D., Jorge, R., and Comesaña, P. (2022). Wearing mask hinders emotion recognition, but enhances perception of attractiveness. *Personal. Individ. Differ.* 184:111195. doi: 10.1016/j.paid.2021.111195

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Pezzulo, G., Iodice, P., Barca, L., Chausse, P., Monceau, S., and Mermillod, M. (2018). Increased heart rate after exercise facilitates the processing of fearful but not disgusted faces. *Sci. Rep.* 8:398. doi: 10.1038/s41598-017-18761-5

Ponsi, G., Panasiti, M. S., Aglioti, S. M., and Liuzza, M. T. (2017). Right-wing authoritarianism and stereotype-driven expectations interact in shaping intergroup trust in one-shot vs multiple-round social interactions. *PLoS One* 12:e0190142. doi: 10.1371/journal.pone.0190142

Qi, Y., Luo, Y., Feng, Y., Chen, Z., Li, Q., Du, F., et al. (2021). Trustworthy faces make people more risk-tolerant: the effect of facial trustworthiness on risk decision-making under gain and loss conditions. *PsyCh J.* 11, 43–50. doi: 10.1002/pchj.498

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Schroeter, M. L., Kynast, J., Villringer, A., and Baron-Cohen, S. (2021). Face masks protect from infection but may impair social cognition in older adults and people with dementia. *Front. Psychol.* 12:640548. doi: 10.3389/fpsyg.2021.640548

Singmann, H., and Kellen, D. (2019). An introduction to mixed models for experimental psychology. *New Meth. Cogn. Psychol.* 28, 4–31. doi: 10.4324/9780429318405-2

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BRIEF RESEARCH REPORT
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Are Face Masks a Problem for Emotion Recognition? Not When the Whole Body Is Visible

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The rise of the novel COVID-19 virus has made face masks commonplace items around the globe. Recent research found that face masks significantly impair emotion recognition on isolated faces. However, faces are rarely seen in isolation and the body is also a key cue for emotional portrayal. Here, therefore, we investigated the impact of face masks on emotion recognition when surveying the full body. Stimuli expressing anger, happiness, sadness, and fear were selected from the BEAST stimuli set. Masks were added to these images and participants were asked to recognize the emotion and give a confidence level for that decision for both the masked and unmasked stimuli. We found that, contrary to some work viewing faces in isolation, emotion recognition was generally not impaired by face masks when the whole body is present. We did, however, find that when viewing masked faces, only the recognition of happiness significantly decreased when the whole body was present. In contrast to actual performance, confidence levels were found to decline during the Mask condition across all emotional conditions. This research suggests that the impact of masks on emotion recognition may not be as pronounced as previously thought, as long as the whole body is also visible.

Keywords: COVID-19, face masks, emotion recognition, body perception, face emotion

INTRODUCTION

Accurate emotion recognition enables humans to sustain relationships crucial for survival, cooperative living, and reproduction (Chen, 2019). Most non-verbal emotion recognition chiefly relies on facial and bodily cues (de Gelder and Van den Stock, 2011; Jack and Schyns, 2015) and successful non-verbal interactions can only occur if there is mutual understanding and recognition of what the other party is expressing.

The face is arguably the most informative visual stimulus in human perception (Ekman et al., 1980). The face's high social visibility, accessibility and expressiveness make it a prime vehicle for exchanging emotional information (Hager and Ekman, 1979; Schmidt and Cohn, 2001). However, facial emotion recognition can be impaired by facial occlusion (Wegrzyn et al., 2017). Indeed, when a person's face is obscured, the perceiver's emotion recognition ability is impaired, as they are left with only the remaining visible social information to rely on (Spitzer, 2020). Therefore, they tend to reconstruct the face to make an informed interpretation—with the mouth and eyes having more weight on correct reconstruction (Nestor et al., 2020).

How distinct types of occlusions interfere with emotion recognition is contingent on the emotions themselves. There has been culturally varied research on the impact of partial occlusions, such as from shawls, caps (Kret and De Gelder, 2012) and niqabs (Fischer et al., 2012). It was found that when only the upper half of the face was visible, participants were able to accurately recognize negative emotions more readily than positive ones—thus suggesting the eyes are more integral for expressing more negative emotions. For example, Nestor et al. (2020) argue that the squinting of the eyes from smiling can be misconstrued as skepticism, therefore indicating occlusion of the mouth may enhance the perception of negative emotions while reducing positive perceptions. Indeed, Maurer et al. (2002) argue that partially obscuring a face disrupts holistic face processing, meaning certain facial features cannot be processed relationally to other features. For example, if a person were wearing a niqab, the perceiver would be unable to create a coherent gestalt of the face, as their processing of the eyes in the context of having a nose and a mouth beneath it would be disrupted.

In the current climate of the COVID-19 pandemic—faces are regularly partially obscured by face masks. Whilst masks help prevent the spread of viruses and protect those most at risk (Wu and McGoogan, 2020), they also propel humanity into a unique conundrum when trying to read a masked individual's non-verbal emotional expressions (Pavlova and Sokolov, 2022). Because masks cover $\sim$ 60–70% of the face relevant for emotional expression (Carbon, 2020), observers only have the top half of the face for emotion detection. Nestor et al. (2020) argued this new, masked norm brings with it a potentially "radical change to human psychosocial dynamics and communication." Indeed, whilst previous research indicates that occlusion of the mouth area has a significant impact on accurate recognition of happy states, up until the beginning of the Covid-19 pandemic, there was limited research regarding the actual implications of mask-wearing (Chua et al., 2020).

That being said, Carbon (2020) study proposes a link between face-mask wearing and decreasing ability to recognize an individual's emotion. Whilst finding a clear performance drop in emotion recognition accuracy viewing masked stimuli (except for fearful and neutral faces), they also observed a marked drop in confidence levels during the mask condition.

There have been several other recent papers describing decreases in emotion recognition in faces (Ruba and Pollak, 2020; Grundmann et al., 2021; McCrackin et al., 2022), identity and expression recognition (Carragher and Hancock, 2020; Noyes et al., 2021; Grahlow et al., 2022; Kim et al., 2022), expression intensity (Tsantani et al., 2022), memory for faces (Freud et al., 2020), connectedness to the speaker (Mheidly et al., 2020; Saunders et al., 2021), perception of attractiveness (Parada-Fernández et al., 2022) and trust attribution (Biermann et al., 2021; Marini et al., 2021). Face masks would therefore appear to have quite a detrimental effect on normal social interaction. All of these studies, however, have something in common; they use stimuli in which the face is the only body part visible.

However, in situations where one might see a face mask (during face-to-face interactions rather than online interactions) faces are rarely seen in isolation. Facial expressions are nearly always seen as an indistinguishable entity of social information, accompanied by body language, vocal cues, hand gestures and posture. Indeed, emotions can be reliably recognized from the body alone when facial information is removed (Atkinson et al., 2004; Van den Stock et al., 2007; Ross et al., 2012; Ross and Flack, 2020), suggesting that the body and the face yield similar emotion detection capacity.

In the first comprehensive review on reading masked faces, Pavlova and Sokolov (2022) argue that while facial expressions may be kept under reasonable control, body movements can reveal our true feelings. As such, they argue that given the rich sources of non-verbal information such as body language and prosody available to a viewer, these should also be taken into account when investigating the impact of face masks on social interaction. This is something which in our opinion has not yet been explored in any detail in the literature.

Previous literature also argues that emotional face recognition is significantly improved when in conjunction with congruent bodily expressions (Kret et al., 2013). Mondloch (2012) further contends that when there is a disruption to this congruence, such as a sad face paired with an angry body, individuals will preferentially attend to the face over the body to make an emotional recognition decision. Therefore, if a mask if partially obscuring a face, this could affect the integration of face-body emotional information resulting in ambiguous or unclear emotion recognition. This is reflected in eye-tracking data, which reveals that during social interactions, there are more frequent and more prolonged fixations on the face compared to the body (Shields et al., 2012). Whilst this is true during general interaction, research suggests eye movements fluctuate depending on the emotion portrayed (Kret et al., 2013). For example, eye movements attended bodily cues (particularly the hands) to a greater extent when perceiving angry and fearful emotions than happy or sad expressions (Fridin et al., 2009). In most "body-only" stimuli the face is blurred out, forcing participants to determine the emotion from the body. It could be the case therefore, that in situations where the face is obscured with a mask, the body "picks up the slack" and identification is still possible. Alternatively, it could be the case that as above, when the face is present (masked or not), it is the preferred modality for emotion recognition, and the presence of the body has little impact on recognition accuracy. Will the findings of a detrimental impact of masks (which one can see throughout the literature) hold when the body is available?

Although there has been work researching the impact of face masks using the face in isolation, to our knowledge, this is the first exploration of the impact of face masks whilst surveying the entire expressive body. Therefore, unlike other studies using isolated faces, this study will feature the whole body in conjunction with the face, thus creating a more realistic presentation of encountering a mask-wearing individual. Using a full-body set of static stimuli (de Gelder and Van den Stock, 2011), this study investigates whether wearing a face mask impacts emotion recognition accuracy when surveying the full-body for anger, happiness, sadness, and fear. To further delve into this concept, similar to Carbon (2020), the individual's reported confidence levels when making that initial deduction of emotion recognition were also investigated.

It was first hypothesized that face masks would significantly impair the general accuracy of emotion recognition for all emotion conditions except fear, reflecting Carbon (2020) study. We further hypothesized that reports of confidence in the accuracy of their choice would be significantly lower in all emotions with a mask than without a mask.

METHODOLOGY

Participants

We conducted a power analysis to justify our choice of sample size. We based our predicted effect size on calculations in the surgical face mask paper of Carragher and Hancock (2020). They in turn took the effect size from Kramer and Ritchie (2016) which was $\eta^2 = 0.13$ in a one-way ANOVA with three conditions. An a priori power analysis indicated that a total of 62 participants would be needed to achieve 80% power to detect an effect of $\eta^2{}_p = 0.15$ in a 2×4 within subjects ANOVA as we have here. Therefore 70 participants from the United Kingdom (48 females, 21 males, 1 non-binary; mean age = 29.5, *SD* = 11.4) volunteered and were recruited to participant. All participants provided informed consent and were recruited through the Durham University Psychology Participant Pool and on Prolific Academic. Psychology students completed the experiment in exchange for course credits and prolific academic participants were renumerated for their time.

Stimuli and Materials

Stimuli were taken from the Bodily Expressive Action Stimuli Test (BEAST) (de Gelder and Van den Stock, 2011), which consists of 254 posed whole-body images of 46 actors expressing four emotions (Happiness, Sadness, Anger and Fear). Eighty stimuli (20 for each emotion, 10 males and 10 females) were selected from the total set. Manipulations of the BEAST images were then completed using the photo editing software GNU Image Manipulating Program (GIMP) to create the Mask conditions. Stock images of masks were found from Google Images. These images were individually manipulated to fit onto different stimuli's faces. As in Carragher and Hancock (2020) masks were fitted over the stimuli such that they covered the same features of the face as is recommended in real life; i.e., covering the face from the middle of the nose to below the chin. We also made sure that when the head is slightly turned the mask is seen coming under the chin. Mask straps and shadows were also added to maximize ecological validity. Examples of stimuli can be seen in **Figure 1**.

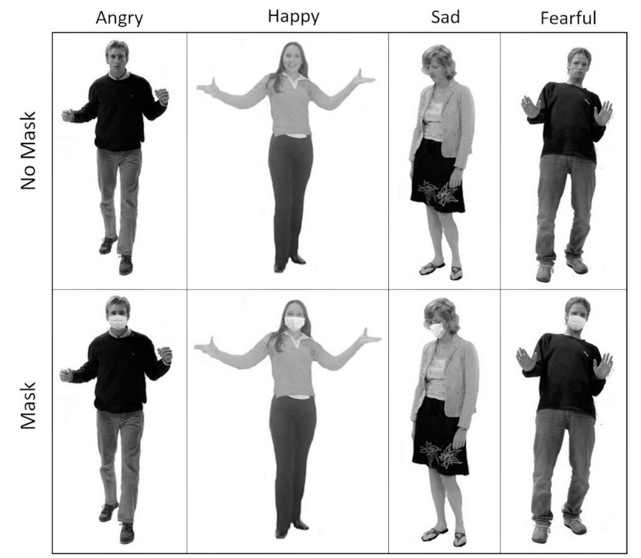

FIGURE 1 | Examples of the manipulated BEAST stimuli displaying the 4 different emotions in the Mask **(top)** and No Mask **(bottom)** conditions. The emotions from left to right; Anger, Happiness, Sadness, Fear.

Design and Procedure

The experiment was conducted using the online survey platform Qualtrics. Each participant saw all 160 stimuli in a randomized order. The stimuli were presented for 4 s. After that, participants were presented with a forced-choice of which emotion they believed the stimuli were expressing—Anger, Happiness, Sadness, or Fear. This was presented in the form of a multiple-choice button. Participants saw both masked and unmasked stimuli and were then asked to assess their confidence level in the accuracy of this choice by using a sliding bar from 0 (Not Confident) to 100 (Extremely Confident). Once this was completed, the participants clicked the "Next" button, and the procedure was repeated with the subsequent randomized stimuli and question set. The procedure lasted approximately 30 min.

RESULTS

Accuracy for Emotion Recognition

Percentage correct emotion identification scores were calculated for each emotion/condition combination for each participant and averaged across all participants to give an overall percentage correct response measure. This gave us a 2 (Mask condition) × 4 (Emotion) design. However, upon inspection of the data distributions using histograms and Q-Q plots it was decided that they did not look normally distributed. A Shapiro-Wilk test confirmed this ($W = 0.839$, $p < 0.001$) and thus non-parametric analyses were performed.

Performing separate Friedman Tests for each factor we first found a significant main effect of Emotion type on recognition ability X^2 (3) = 152.07, $p < 0.001$, Kendall's W = 0.36. Conover's *post-hoc* comparisons and applying Bonferroni correction revealed that Sadness was recognized significantly more accurately than Happiness ($p < 0.001$), Fear ($p = 0.008$) and Anger ($p = 0.01$) (see **Figure 2**).

Friedman Tests for the Mask condition, however, revealed no significant main effect on emotion recognition ability X^2 (1) = 0.34, $p = 0.561$, Kendall's W = 0.012.

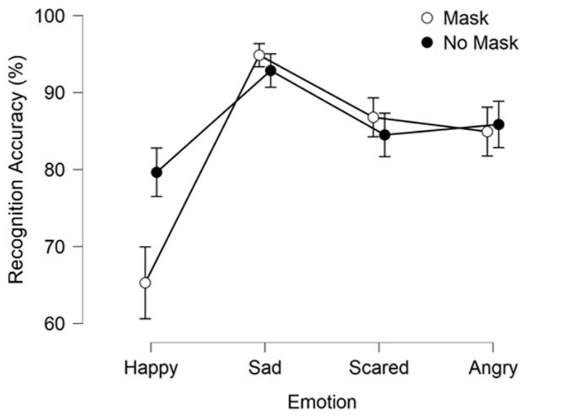

FIGURE 2 | Average recognition rates for both Mask conditions and the four emotions. Error bars represent 95% confidence intervals.

With no clear way of checking for an interaction effect on 2 × 4 non-parametric repeated-measure data, we instead ran 4 Wilcoxon signed-rank tests looking at the differences between the two Mask conditions for each of the 4 Emotion types. Using Bonferroni corrections we found that Happiness was significantly harder ($T = 83$, $z = -6.27$, $p < 0.001$) to recognize in the Masked condition (Median = 70%) compared to the No Mask condition (Median = 80%). We found no significant difference between the Mask conditions across the other 3 emotion types (Sadness: $T = 805$, $z = 2.23$, p = *n.s*; Fear: $T = 871.5$, $z = 2.26$, p = *n.s.*; Anger: $T = 654$, $z = -0.54$, p = *n.s.*).

Confusion Matrices

We know that between the two mask conditions, Happiness was found to be significantly harder to recognize when the face was masked ($T = 83$, $z = -6.27$, $p < 0.001$). Here we wanted to explore whether this effect was due to Happiness being confused for one other emotion specifically. The confusion matrices indicate that within our Mask condition Happiness was not being confused with one emotion in particular, but rather it was confused for Sadness 13.9%, Angry 13.4% and Fear 7.4% of the time (see **Figure 3**). This means that the particularly low emotion recognition rate of Happiness in the Mask condition wasn't because it was being confused with any other emotion in particular, rather there was a spread of incorrect responses across the other 3 choices.

Confidence Levels for Emotion Recognition

As with emotion recognition, the average confidence scores were recorded and entered into a 2 (Masked condition) × 4 (Emotion) analysis of variance (ANOVA). See **Figure 4** for summary of results. Upon inspection of the data distributions using histograms and Q-Q plots it was decided that these data did look normally distributed. This was confirmed by a Shapiro-Wilk test ($W = 0.989$, $p = 0.783$), and thus repeated measure ANOVA were performed.

We found a main effect of emotion [$F(3, 207) = 69.23$, $p < 0.001$]. Bonferroni corrected post-hoc tests showed this to be driven by participants being significantly less confident in their answers for Happiness compared to Sadness ($t = 14.19$, $p < 0.001$), Fear ($t = 9.0$, $p < 0.001$) and Anger ($t = 8.75$, $p < 0.001$) as well as showing more confidence in answers for Sadness than Fear ($t = 5.19$, $p < 0.001$) and Anger ($t = 5.44$, $p < 0.001$).

We also found a main effect of Mask [$F(1, 69) = 60.4$, $p < 0.001$] with confidence in recognition of Masked stimuli (Mean = 69.6%) being significantly lower than No Mask stimuli (Mean = 75.53%).

Finally we found a significant interaction between Masked Condition and Emotion [$F(3, 207) = 26.73$, $p < 0.001$]. Contrary

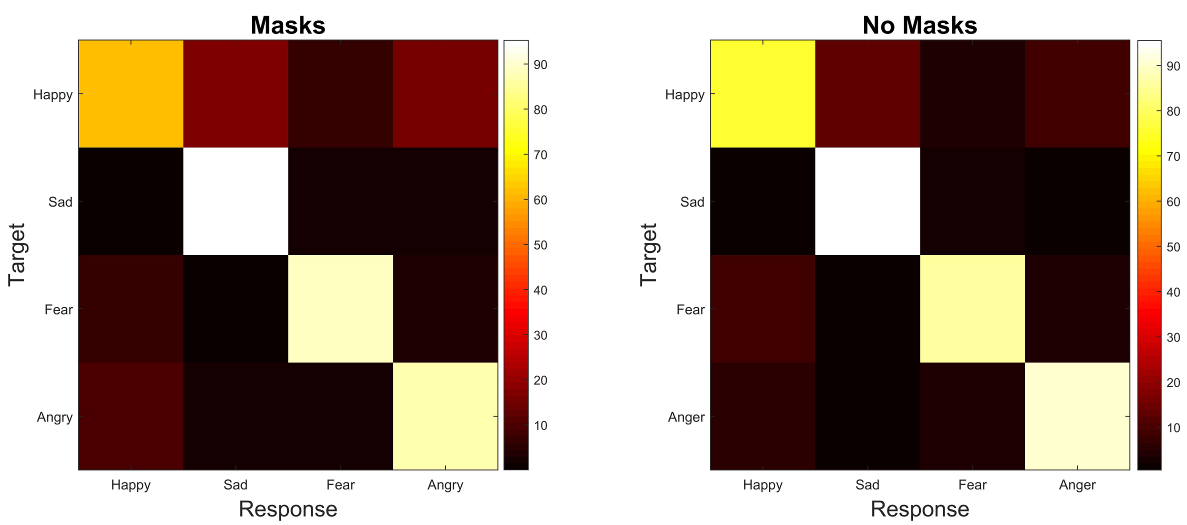

FIGURE 3 | Confusion matrices showing correct emotion response to target emotion (Happiness, Sadness, Fear and Anger) in the two masked conditions (Mask and No Mask). The color bar represents % of responses.

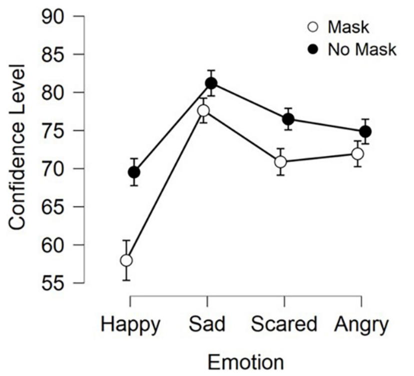

FIGURE 4 | Average confidence levels for both Mask conditions and the four emotions. Error bars represent 95% confidence intervals.

to our recognition accuracy data, Bonferroni corrected paired *t*-tests showed that this interaction was driven by lower confidence in the Masked condition compared to the No Mask condition in all emotions (Happiness: $t = 11.5$, $p < 0.001$; Sadness: $t = 3.56$, $p < 0.005$; Fear: $t = 5.57$, $p < 0.001$; Anger: $t = 2.89$, $p < 0.05$).

DISCUSSION

The present study aimed to explore whether face masks impaired emotion recognition when surveying the full body. We first hypothesized that emotion recognition accuracy would be impaired in all emotions except fear, mirroring Carbon (2020) study. Secondly, we predicted that confidence would be lower when determining the emotion in masked individuals. Our results partially support these hypotheses.

In terms of the first hypothesis, and contrary to the work using isolated faces by Carbon (2020), we instead found that emotion recognition accuracy was only affected when masked full-body stimuli were portraying happiness. We found no detrimental effects of masks in the recognition of sadness, fear or anger.

Despite this largely unaffected recognition, we found that confidence levels in responses were lower for the Masked condition across all emotions.

Emotion Recognition

These results suggest that when the face is not seen in isolation, the impact of mask-wearing on emotion recognition ability is largely unchanged. The exception to this is Happiness, which is primarily portrayed using the face, and the recognition of which in the body has been shown to be ambiguous at times (de Gelder and Van den Stock, 2011; Ross et al., 2012; Ross and Flack, 2020).

Even when unmasked, the drop off in recognition rates for happiness is reflected in several previous studies surrounding emotion recognition from the body (Atkinson et al., 2004; de Gelder and Van den Stock, 2011; Ross and Flack, 2020). This is also consistent with research that contests that happiness is often expressed through the mouth with a smile (Calvo and Nummenmaa, 2016). Indeed, Gavrilescu (2017) found the addition of hand and bodily cues did not substantially increase the recognition of happiness compared to the addition of happy facial expressions. Therefore, this suggests that recognition of happy states is more heavily reliant on the face than the body. In addition to crucial facial information being covered, and as previously mentioned, past research indicates that happy bodily cues can also be ambiguous (de Gelder and Van den Stock, 2011; Ross et al., 2012; Witkower and Tracy, 2019; Ross and Flack, 2020), with Tracy and Robins (2007) finding happy bodily cues are often misinterpreted as other emotions, such as neutrality and pride. If a body is ambiguous and we are unsure, we then may turn to the face for confirmation. If that face then has the main cue for determining happiness obscured, this would perhaps explain the effect that masks have on recognition rates for Happiness. Indeed, we see in our confusion matrices that, on average, participants are confusing Happiness with Sadness and Anger 13.9 and 13.4% of the time, respectively, when people are masked. This may indicate that instead of looking like another emotion in particular, participants are guessing in these instances. Alternatively, these stimuli could look like slightly different emotions for which there is no option in the current design (e.g., exasperation). We have suggested possible solutions to this later in the discussion.

However, contrary to happiness, the lack of impairment in the other emotions is in stark contrast to Carbon (2020) study, which found a significant discrepancy in accuracy recognition when facial stimuli were masked. These emotions arguably have distinctive body postures and configurations which differentiate them (Dael et al., 2012). The slumped shoulders and bent neck are uniquely indicative of sadness, while raised hands as shields or fists construe fear or anger, respectively, (Coulson, 2004; Rosario et al., 2014). Therefore, even with the face obstructed with a mask, the head positioning and body posture is still salient, explaining its easy recognition.

It is also true that fear and anger are most effectively expressed through the eyes and brow – the area left visible by masks (Gosselin and Schyns, 2001; Fischer et al., 2012; Wegrzyn et al., 2017). Alongside anger, fear has particularly expressive body language, as such threat-based expressions are often highly animated as they precede evolutionary actions such as fleeing or fighting (Martinez et al., 2016). In these static stimuli, hand positioning is especially distinctive during angry and fearful emotional states (Ross and Flack, 2020), with common fearful reactions including open palms protecting one's face (Grèzes et al., 2007). In fact, eye-tracking indicates that individuals look longer at the hands of angry and scared stimuli when making emotional judgments (Fridin et al., 2009). This suggests that with the faces masked, either individuals rely more on the remaining bodily information, or that the face is simply not needed to recognize emotion when the whole body is present. Either way, masks do not hinder emotion recognition rates in these stimuli.

Confidence Levels

Despite recognition accuracy remaining unchanged for sadness, fear and anger, confidence levels in responses across all emotions significantly reduced when participants were observing masked stimuli. This is reflected in Carbon (2020) paper, in which he also found a significant reduction in confidence. Such confidence reductions are aligned with the aforementioned models regarding holistic face processing (Maurer et al., 2002). Presumably, the simplest explanation probably holds here, that by presenting less information to people, confidence in one's ability to recognize some aspect of that person will be lowered.

A possible explanation for this reduction in confidence yet intact emotion recognition ability could be the presence of implicit bias. In other words, the assumption that masks will inevitably impact their ability to perceive emotions diminishes their confidence levels. However, the recognition accuracy results indicate that this is not necessarily correct in practice. This pattern of low reported confidence yet intact competence is reflected in Lorey et al. (2012) and their research with alexithymia individuals. A possible implication of this finding is that reduced confidence could result in lowered willingness to engage in pro-social behavior, for fear of misjudging emotional interactions, even though perception remains largely intact.

Implications and Limitations

Here, we have presented evidence that, contrary to previous work investigating the effect of face masks on emotion recognition, when presented with whole bodies rather than isolated faces emotion recognition remains largely unaffected. This should allay some concerns raised by previous work regarding the problems masks raise in emotion recognition. It further implies that when wearing a mask, by emphasizing an emotion through body language, there should be no notable reduction in recognition. This is particularly pertinent for happiness, which did show a significant decrease in recognition accuracy. One could imagine a situation where if our body stimuli contained a distinct "happy" hand signal (e.g., thumbs up) we may have seen no reduction in recognition accuracy.

One limitation of the current study, however, is that although being arguably more ecologically valid than face-only stimuli, the results are still quite specific to these particular stimuli. Here actors were asked to imagine a scenario and act it out (then a photo was taken). For happiness they were asked to imagine seeing a long-lost friend at a train station. Thus, our happy body stimuli have their arms outstretched and are arguably more ambiguous compared to the others.

This leads to another issue with these particular stimuli, namely the lack of nuance in the emotions presented. By adding emotions that are less apparent from the body (embarrassment or pride), this may "force" participants to look at the face. Indeed, including a condition in which the faces of the stimuli are seen in isolation would be of great benefit. Here, the resolution of the current stimuli would not allow us to explore this effectively, but by including a face only condition, the contribution of the face in these stimuli compared to the body could be examine in more depth. Although it is not our main intention here, investigating the extent to which the face is "used" in emotion recognition when the face is masked and the whole body is visible would be a very interesting avenue of research to pursue. Either through eye-tracking or fMRI one could imagine quantifying the amount of attention the face gets in these stimuli and understanding whether the body is the main focus.

One must also consider the potential gender differences across participants as here we have a 2:1 gender split in favor of females. Although we find no differences in recognition rates across males and females in the current study, previous research has found that females tend to score higher in emotion recognition tasks at a variety of ages (Grosbras et al., 2018; Abbruzzese et al., 2019; Olderbak et al., 2019). Future work should bear this in mind and endeavor to achieve an equal gender split in participants.

Age as well may play a role in our results. Looking at our confusion matrices, a possible explanation for Happiness being confused more than other emotions could be the positive bias in emotion perception described in the literature for older individuals/negative bias in younger individuals (Di Domenico et al., 2015). Our participants were on average 29 years old, so perhaps Happiness was being recognized as one of the other 3 negative emotions in this case more often than perhaps it might have been had our participants been older. One way to counter this possibility in the future is to have a balance of "positive" and "negative" emotions, instead of the 1:3 ratio we have here.

Future work may also want to remove the forced choice element of the design. Happiness in the Mask condition was mostly confused with Sadness and Anger, but in a forced choice task the confusion is also forced. Perhaps the stimuli actually looked confused, or showed annoyance, and the labels provided were the closest available alternative. By allowing open choice emotional questioning it would allow for more nuance to be observed in the stimuli, and the effect of masks and emotion recognition to be explored with more emphasis on the potential confusion and ambiguity created by masks.

In our view using whole bodies in this context is a more ecologically valid method than using isolated faces. However, they are static images which are still suboptimal. Dynamic videos would be preferable, with research showing that emotion recognition is considerably improved when observing moving stimuli (Dittrich et al., 1996; Atkinson et al., 2004; Dael et al., 2012). Perhaps stimuli with less extreme poses of the given emotions would be preferable, either taken from media (e.g., films) or created specifically for this purpose.

CONCLUSION

To conclude, this study reveals novel results with globally reaching implications. It uncovers the first evidence of emotion recognition from the full body whilst wearing masks and demonstrates that aside from happiness, recognition is unaffected. It also serves to allay some of the concern previously raised by research suggesting that masks severely impact emotion recognition. Indeed, such studies surrounding the COVID-19 pandemic have suggested that the rise of face masks may bring with it a new dawn of compromised emotional communication (Carbon, 2020; Nestor et al., 2020). However, whilst confidence levels generally decline and emotion recognition of happiness decreases when these stimuli are masked, using these stimuli recognition for other emotions is left unchanged. This suggests that the impairment is perhaps not severe enough to warrant any considerable implications for most emotional interactions. It does suggest that we could express happiness in different ways, particularly regarding making more overt gestural expressions of happiness (Mheidly et al., 2020). This is especially important when one considers the impact that face masks have had on those with hearing loss. In a recent study, over 80% of adults who were deaf or hard of hearing reported difficulty understanding others who wore face masks (Poon and Jenstad, 2022). Therefore, it should be noted that these types of studies focusing on visual posed stimuli do so while negating the vocal modality. In a social interaction one is likely to be able to hear the other person as well as view their whole body, thus future work could also incorporate vocal emotions and explore multimodal emotion recognition with dynamic stimuli to further increase ecological validity.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/p5eh4/.

ETHICS STATEMENT

The study was approved by the Durham University Psychology Department ethics committee, reference: PSYCH-2020-07-02T21_48_20-dwqg21. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

PR and EG designed, conducted the study, and drafted the manuscript. EG created the stimuli. PR analyzed the data. Both authors read and approved the final manuscript.

REFERENCES

Abbruzzese, L., Magnani, N., Robertson, I. H., and Mancuso, M. (2019). Age and gender differences in emotion recognition. *Front. Psychol.* 10:2371. doi: 10.3389/fpsyg.2019.02371

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., and Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception* 33, 717–746. doi: 10.1068/p5096

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: an experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Calvo, M. G., and Nummenmaa, L. (2016). Perceptual and affective mechanisms in facial expression recognition: an integrative review. *Cogn. Emot.* 30, 1081–1106. doi: 10.1080/02699931.2015.1049124

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carragher, D. J., and Hancock, P. J. (2020). Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cogn. Res. Principles Implications* 5:59. doi: 10.1186/s41235-020-00258-x

Chen, J. (2019). Exploring the impact of teacher emotions on their approaches to teaching: a structural equation modelling approach. *Br. J. Educ. Psychol.* 89, 57–74. doi: 10.1111/bjep.12220

Chua, M. H., Cheng, W., Goh, S. S., Kong, J., Li, B., Lim, J. Y., et al. (2020). Face masks in the new COVID-19 normal: materials, testing, and perspectives. *Research* 2020:7286735. doi: 10.34133/2020/7286735

Coulson, M. (2004). Attributing emotion to static body postures: recognition accuracy, confusions, and viewpoint dependence. *J. Nonverbal Behav.* 28, 117–139. doi: 10.1023/B:JONB.0000023655.25550.be

Dael, N., Mortillaro, M., and Scherer, K. R. (2012). Emotion expression in body action and posture. *Emotion* 12, 1085–1101. doi: 10.1037/a0025737

de Gelder, B., and Van den Stock, J. (2011). The Bodily Expressive Action Stimulus Test (BEAST). construction and validation of a stimulus basis for measuring perception of whole body expression of emotions. *Front. Psychol.* 2:181. doi: 10.3389/fpsyg.2011.00181

Di Domenico, A., Palumbo, R., Mammarella, N., and Fairfield, B. (2015). Aging and emotional expressions: is there a positivity bias during dynamic emotion recognition? *Front. Psychol.* 6:1130. doi: 10.3389/fpsyg.2015.01130

Dittrich, W. H., Troscianko, T., Lea, S. E., and Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception* 25, 727–738. doi: 10.1068/p250727

Ekman, P., Friesen, W. V., O'Sullivan, M., and Scherer, K. (1980). Relative importance of face, body, and speech in judgments of personality and affect. *J. Pers. Soc. Psychol.* 38:270. doi: 10.1037/0022-3514.38.2.270

Fischer, A. H., Gillebaart, M., Rotteveel, M., Becker, D., and Vliek, M. (2012). Veiled emotions: the effect of covered faces on emotion perception and attitudes. *Soc. Psychol. Personal. Sci.* 3, 266–273. doi: 10.1177/1948550611418534

Freud, E., Stajduhar, A., Rosenbaum, R. S., Avidan, G., and Ganel, T. (2020). The COVID-19 pandemic masks the way people perceive faces. *Sci. Rep.* 10:22344. doi: 10.1038/s41598-020-78986-9

Fridin, M., Barliya, A., Schechtman, E., de Gelder, B., and Flash, T. (2009). "Computational model and human perception of emotional body language (EBL)," in *Proceeding of the Symposium on Mental States, Emotions and their Embodiment*, (Edinburgh).

Gavrilescu, M. (2017). Recognizing human gestures in videos by modeling the mutual context of body position and hands movement. *Multimedia Systems* 23, 381–393. doi: 10.1007/s00530-016-0504-y

Gosselin, F., and Schyns, P. G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Res.* 41, 2261–2271. doi: 10.1016/S0042-6989(01)00097-9

Grahlow, M., Rupp, C. I., and Derntl, B. (2022). The impact of face masks on emotion recognition performance and perception of threat. *PLoS One* 17:e0262840. doi: 10.1371/journal.pone.0262840

Grèzes, J., Pichon, S., and de Gelder, B. (2007). Perceiving fear in dynamic body expressions. *NeuroImage* 35, 959–967. doi: 10.1016/j.neuroimage.2006.11.030

Grosbras, M.-H., Ross, P. D., and Belin, P. (2018). Categorical emotion recognition from voice improves during childhood and adolescence. *Sci. Rep.* 8:14791. doi: 10.1038/s41598-018-32868-3

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hager, J. C., and Ekman, P. (1979). Long-distance of transmission of facial affect signals. *Ethol. Sociobiol.* 1, 77–82. doi: 10.1016/0162-3095(79)90007-4

Jack, R. E., and Schyns, P. G. (2015). The human face as a dynamic tool for social communication. *Curr. Biol.* 25, R621–R634. doi: 10.1016/j.cub.2015.05.052

Kim, G., Seong, S. H., Hong, S.-S., and Choi, E. (2022). Impact of face masks and sunglasses on emotion recognition in South Koreans. *PLoS One* 17:e0263466. doi: 10.1371/journal.pone.0263466

Kramer, R. S., and Ritchie, K. L. (2016). Disguising superman: How glasses affect unfamiliar face matching. *Appl. Cogn. Psychol.* 30, 841–845. doi: 10.1002/acp.3261

Kret, M., and De Gelder, B. (2012). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Kret, M. E., Roelofs, K., Stekelenburg, J., and de Gelder, B. (2013). Emotional signals from faces, bodies and scenes influence observers' face expressions, fixations and pupil-size. *Front. Hum. Neurosci.* 7:810. doi: 10.3389/fnhum.2013.00810

Lorey, B., Kaletsch, M., Pilgramm, S., Bischoff, M., Kindermann, S., Sauerbier, I., et al. (2012). Confidence in emotion perception in point-light displays varies with the ability to perceive own emotions. *PLoS One* 7:e42169. doi: 10.1371/journal.pone.0042169

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Martinez, L., Falvello, V. B., Aviezer, H., and Todorov, A. (2016). Contributions of facial expressions and body language to the rapid perception of dynamic emotions. *Cogn. Emot.* 30, 939–952. doi: 10.1080/02699931.2015.1035229

Maurer, D., Le Grand, R., and Mondloch, C. J. (2002). The many faces of configural processing. *Trends Cogn. Sci.* 6, 255–260. doi: 10.1016/S1364-6613(02)01903-4

McCrackin, S. D., Capozzi, F., Mayrand, F., and Ristic, J. (2022). Face masks impair basic emotion recognition: group effects and individual variability. *Soc. Psychol.* doi: 10.1027/1864-9335/a000470 [Epub ahead of print].

Mheidly, N., Fares, M. Y., Zalzale, H., and Fares, J. (2020). Effect of face masks on interpersonal communication during the COVID-19 pandemic. *Front. Public Health* 8:582191. doi: 10.3389/fpubh.2020.582191

Mondloch, C. J. (2012). Sad or fearful? the influence of body posture on adults' and children's perception of facial displays of emotion. *J. Exp. Child Psychol.* 111, 180–196.

Nestor, M. S., Fischer, D., and Arnold, D. (2020). Masking our emotions: Botulinum toxin, facial expression, and well-being in the age of COVID-19. *J. Cosmetic Dermatol.* 19, 2154–2160. doi: 10.1111/jocd.13569

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Olderbak, S., Wilhelm, O., Hildebrandt, A., and Quoidbach, J. (2019). Sex differences in facial emotion perception ability across the lifespan. *Cogn. Emot.* 33, 579–588.

Parada-Fernández, P., Herrero-Fernández, D., Jorge, R., and Comesaña, P. (2022). Wearing mask hinders emotion recognition, but enhances perception of attractiveness. *Personal. Individual Differ.* 184:111195.

Pavlova, M. A., and Sokolov, A. A. (2022). Reading covered faces. *Cereb. Cortex* 32, 249–265.

Poon, B. T., and Jenstad, L. M. (2022). Communication with face masks during the COVID-19 pandemic for adults with hearing loss. *Cogn. Res. Principles Implicat.* 7:24.

Rosario, J. L., Diógenes, M. S. B., Mattei, R., and Leite, J. R. (2014). Differences and similarities in postural alterations caused by sadness and depression. *J. Bodywork Movement Therapies* 18, 540–544. doi: 10.1016/j.jbmt.2013.12.010

Ross, P., and Flack, T. (2020). Removing hand form information specifically impairs emotion recognition for fearful and angry body stimuli. *Perception* 49, 98–112. doi: 10.1177/0301006619893229

Ross, P. D., Polson, L., and Grosbras, M.-H. E. (2012). Developmental changes in emotion recognition from full-light and point-light displays of body movement. *PLoS One* 7:e44815. doi: 10.1371/journal.pone.0044815

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Saunders, G. H., Jackson, I. R., and Visram, A. S. (2021). Impacts of face coverings on communication: an indirect impact of COVID-19. *Int. J. Audiol.* 60, 495–506. doi: 10.1080/14992027.2020.1851401

Schmidt, K. L., and Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression research. *Am. J. Phys. Anthropol.* 116, 3–24.

Shields, K., Engelhardt, P. E., and Ietswaart, M. (2012). Processing emotion information from both the face and body: an eye-movement study. *Cogn. Emot.* 26, 699–709.

Spitzer, M. (2020). Masked education? the benefits and burdens of wearing face masks in schools during the current Corona pandemic. *Trends Neurosci. Educ.* 20:100138. doi: 10.1016/j.tine.2020.100138

Tracy, J. L., and Robins, R. W. (2007). The prototypical pride expression: development of a nonverbal behavior coding system. *Emotion* 7:789. doi: 10.1037/1528-3542.7.4.789

Tsantani, M., Podgajecka, V., Gray, K. L., and Cook, R. (2022). How does the presence of a surgical face mask impair the perceived intensity of facial emotions? *PLoS One* 17:e0262344. doi: 10.1371/journal.pone.0262344

Van den Stock, J., Righart, R., and de Gelder, B. (2007). Body expressions influence recognition of emotions in the face and voice. *Emotion* 7, 487–494.

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. how individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Witkower, Z., and Tracy, J. L. (2019). Bodily communication of emotion: evidence for extrafacial behavioral expressions and available coding systems. *Emot. Rev.* 11, 184–193.

Wu, Z., and McGoogan, J. M. (2020). Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA* 323, 1239–1242. doi: 10.1001/jama.2020.2648

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Wearing the face mask affects our social attention over space

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Recent studies suggest that covering the face inhibits the recognition of identity and emotional expressions. However, it might also make the eyes more salient, since they are a reliable index to orient our social and spatial attention. This study investigates (1) whether the pervasive interaction with people with face masks fostered by the COVID-19 pandemic modulates the processing of spatial information essential to shift attention according to other's eye-gaze direction (i.e., gaze-cueing effect: GCE), and (2) whether this potential modulation interacts with motor responses (i.e., Simon effect). Participants were presented with face cues orienting their gaze to a congruent or incongruent target letter location (gaze-cueing paradigm) while wearing a surgical mask (Mask), a patch (Control), or nothing (No-Mask). The task required to discriminate the identity of the lateralized target letters by pressing one of two lateralized response keys, in a corresponding or a non-corresponding position with respect to the target. Results showed that GCE was not modulated by the presence of the Mask, but it occurred in the No-Mask condition, confirming previous studies. Crucially, the GCE interacted with Simon effect in the Mask and Control conditions, though in different ways. While in the Mask condition the GCE emerged only when target and response positions corresponded (i.e., Simon-corresponding trials), in the Control condition it emerged only when they did not correspond (i.e., Simon-non-corresponding trials). These results indicate that people with face masks induce us to jointly orient our visual attention in the direction of the seen gaze (GCE) in those conditions resembling (or associated with) a general approaching behavior (Simon-corresponding trials). This is likely promoted by the fact that we tend to perceive wearing the mask as a personal safety measure and, thus, someone wearing the face mask is perceived as a trustworthy person. In contrast, people with a patch on their face can be perceived as more threatening, therefore inducing a GCE in those conditions associated with a general avoidance behavior (Simon-non-corresponding trials).

KEYWORDS

face mask, social cognition and interaction, gaze-cueing, Simon effect, COVID-19

Introduction

Humans are embedded in a social context and typically spend a significant amount of time interacting with other individuals and with objects in their environment. The spread of the COVID-19 pandemic has required large-scale habits change, ranging from self-isolation and social distancing to the pervasive use of the surgical face mask in everyday life. By heavily transforming the context surrounding us, COVID-19 has consequently transformed the way we interact with others. For instance, it has become relevant to assess whether the distance between us and the others is appropriate and, more importantly, whether other individuals near us are wearing the facemask or not.

While surgical masks have had a positive effect on preventing virus transmission (Liang et al., 2020), it seems that, by occulting a large portion of the human face, they interfere with the processing of key information that supports social interactions. Research conducted during the pandemic has highlighted that face-covering hampers face identification and perception (for a review, see Pavlova and Sokolov, 2022). Several studies revealed that face masks affect identity recognition, by altering face perception abilities (e.g., Freud et al., 2020; Noyes et al., 2021) and by reducing discrimination between familiar and unfamiliar faces (Carragher and Hancock, 2020). Others have shown that face masks diminish the ability to accurately classify emotions and facial expressions. For example, Carbon (2020) found that many emotional states, such as happy, sad, and angry were misinterpreted as neutral when the mask covered the lower face parts (see also Parada-Fernández et al., 2022; for theoretical discussion, see Nestor et al., 2020). Similarly, evidence from studies on scholar-aged children (Carbon and Serrano, 2021; see also Ruba and Pollak, 2020) revealed that masked faces impaired children's emotional reading abilities to a different extent; with a strong effect on negative emotions, such as disgust, fear, and sadness, and a relative or null impairment in recognition of anger and neutral expressions. Marini et al. (2021) compared the ability to recognize attributes of faces when these were presented without the mask, with a standard surgical mask, and with a transparent surgical mask. They found that the transparent surgical mask, but not the standard mask, facilitated the recognition of emotional expressions and enhanced trustworthiness judgments; however, transparent masks impaired the re-identification of the same unmasked face, similar to the standard masks.

Interestingly, face masks impact not only identity and emotions recognition but also persons' perception and social trait judgments. Olivera-La Rosa et al. (2020) asked participants to rate the perceived trustworthiness and sickness of, and desired social distance (i.e., social distance scale, Bogardus, 1933) from target faces wearing the surgical mask or not. They found that, compared to standard face target stimuli, faces wearing a surgical mask were perceived as more likely to be ill, but at the same time also as more trustworthy and more socially desirable for having closer interactions. The authors interpreted these results as a consequence of the internalization of social norms of wearing masks and keeping social distance imposed by the pandemic, which resulted in judging mask-wearers as more responsible and socially compliant, thereby promoting approach behaviors towards them. Similarly, Oldmeadow and Koch (2021) showed that masks increased the perceived trustworthiness and attractiveness of both Black or White faces, suggesting that the positive value of face masks is not influenced by racial profiling. In contrast, other studies have highlighted a negative bias in trustworthiness appraisals of masked faces. For example, Malik et al. (2021) showed videos of masked or unmasked actors offering economical advice to more than 2000 US citizens and found that only 5% trusted the advice given by masked strangers than when it was given by the unmasked strangers. In a rating study by Biermann et al. (2021), masked faces were evaluated as less trustworthy and less happy than unmasked faces; however, this effect was attenuated in participants who experienced high psychological distress and risk perception associated with the pandemic, and who showed high compliance with prevention measures to avoid infection. In a set of experiments, Twele et al. (2022) pointed out that facial masks might have a limited impact in forming first impressions of unfamiliar faces from across the lifespan. Specifically, they found that young adult faces with happy expressions were rated as more trustworthy than neutral faces, even when the same face had been previously seen with a mask; and that the presence of masks does not affect the adult's perceived niceness of childs' faces and the trustworthiness and competence of older adults face. The studies described above yielded contrasting results on whether and to what extent face masks affect interpersonal trust, likely due to the fact that they used different methodologies and stimuli. Nevertheless, the topic is of paramount interest and it might be relevant to investigate the impact of face masks on other social and cognitive processes.

Furthermore, it is worth noting that by covering the lowest part of the face, the face mask also increases the relevance of the eyes, a region that is known to play a particular role in human social interactions by providing a rich source of information to infer other's intentions, emotional and mental states (e.g., Baron-Cohen et al., 2001; for recent reviews, see Grossmann, 2017; Capozzi and Ristic, 2018) and more generally to orient our own attention toward others (see Dalmaso et al., 2020).

The present work intends to explore whether wearing face masks that leave only the eyes region visible could impact social cognition, and more specifically two well-known attentional mechanisms, such as the gaze-cueing effect (GCE; for a review, see Frischen et al., 2007) and the Simon effect (e.g., Simon and Rudell, 1967; Simon, 1990; for a review, see Rubichi et al., 2006).

The GCE, a highly sensitive and reliable index of social attention, refers to the automatic tendency to shift attention towards the spatial location indicated by a task-irrelevant face with an averted gaze. In the standard gaze-cueing paradigm, participants are presented with a cue face on the screen that first looks straight ahead and then turns its gaze to the left or the right side. Shortly after this gaze shifting, a target letter either appears on a side congruent or incongruent to the gaze direction.

Participants are asked to respond as quickly as possible to the identity of the target letter by pressing a button on the keyboard. People typically respond faster to targets appearing in the same location gazed at by the cue face (i.e., gaze-congruent trials) than to targets appearing in a location opposite to that gazed at by the cue face (i.e., gaze-incongruent trials), even though gaze direction is irrelevant to the task, thus indicating an automatic nature of social attention (Friesen and Kingstone, 1998; Driver et al., 1999; Langton and Bruce, 1999; Dalmaso et al., 2020).

The Simon effect (Simon, 1969, 1990) is characterized by a faster and more accurate performance when stimulus position and response position spatially correspond (i.e., corresponding condition) compared to when they do not correspond (i.e., non-corresponding condition), even though stimulus position is irrelevant to the task (e.g., Pellicano et al., 2009, 2019; Baroni et al., 2012; Lugli et al., 2013, 2016, 2017; Scerrati et al., 2017; D'Ascenzo et al., 2018, 2020). This difference in performance is thought to emerge because the stimulus location, although irrelevant, is being processed and leads to the automatic activation of the response that spatially corresponds with it. Therefore, in corresponding trials, the automatically activated response corresponds to the response required by task instructions, thus producing a more efficient performance. Conversely, in non-corresponding trials, the automatically activated response conflicts with the one indicated by task instructions, leading to slowed response times and increased errors (e.g., dual-route model, Kornblum et al., 1990; De Jong et al., 1994).

It is worth emphasizing that the GCE and the Simon effect have at least two main characteristics in common. The first is the need to extract a spatial code: for the GCE in order to direct the attention towards the gaze of the cue stimuli, and for the Simon effect in order to automatically process the position and the correspondence between stimulus and response. Second, both the effects can be modulated by different social factors. As for the GCE, the social factors previously investigated concern the observer, the cueing face or their specific relation. In particular, the face gender (e.g., Bayliss et al., 2005); age (e.g., Slessor et al., 2010, see also Ciardo et al., 2014); shared group-membership (e.g., Pavan et al., 2011; Dalmaso et al., 2014); competitive or cooperative behaviours (Ciardo et al., 2015); the perceived dominance and status (e.g., Jones et al., 2010; Dalmaso et al., 2012; Ciardo et al., 2021); trustworthiness (e.g., Süßenbach and Schönbrodt, 2014; Mattavelli et al., 2021); and emotional expressions (e.g., Bonifacci et al., 2008; Ricciardelli et al., 2012, 2016; for a recent review, see Dalmaso et al., 2020). Indeed, all these social factors have been shown to modulate the magnitude of the GCE. For example, stronger gaze-cueing effects were observed in response to faces described as belonging to trustworthy individuals compared to untrustworthy ones (Süßenbach and Schönbrodt, 2014) or when the gaze was perceived as more familiar (Deaner et al., 2007). However, Carraro et al. (2017) also showed that faces associated with negative/antisocial behaviors triggered stronger GCE than faces associated with positive/prosocial behaviors, and this effect was marked for participants who evaluated antisocial behaviors more negatively. Overall, it has been widely recognized that facial features convey crucial information for social interaction and provide cues to guide our behaviors towards others.

As for the Simon effect, several studies reported modulation of the effect according to the social relation between participants. In particular, Sebanz et al. (2003) were the first to show that the effect occurs even when the task is shared between two participants and different social factors are manipulated (e.g., Hommel et al., 2009; Iani et al., 2014, 2021; Lugli et al., 2015; Ciardo et al., 2016; Ruissen and de Bruijn, 2016). For example, some studies investigated the influence of interpersonal relationships: positive/bad mood or positive/negative relationship with the co-actor (i.e., participants with whom the task is shared), competitive/cooperative instructions to participants modulated the occurrence or the magnitude of the effect (e.g., Hommel et al., 2009; Kuhbandner et al., 2010; Iani et al., 2011; for a review Dolk et al., 2014).

Given the increasing amount of evidence showing how wearing facemasks profoundly affects our ability to regulate efficient social interactions, we aimed at exploring whether the presence of the surgical mask on a face impacts attention to the same extent as other social factors that previous works reported as successful in influencing the GCE and the Simon effect. The present work implemented a gaze-cueing paradigm where a horizontal left/right keypress response set has been used in order to investigate at the same time two effects (i.e., GCE and Simon). It is worth noting, in fact, that research implementing a gaze-cueing paradigm typically adopts a vertical up/down keypress response set to avoid any concurrent variance that might be produced by the relation between stimulus position and stimulus response (see, for example, Driver et al., 1999). In the few studies implementing a gaze-cueing paradigm where a horizontal left/right keypress response set has been used, the relation between stimulus position and stimulus response has not been taken into account and analyzed systematically (e.g., Dalmaso et al., 2012, 2014; Carraro et al., 2017).

More specifically, we conducted an online study in which the participants were shown a set of cue faces with averted gaze, looking either toward the left or toward the right. They were asked to perform a gaze-cueing task by pressing a lateralized response key associated with a specific target letter. The target could appear in a lateral position that could be either congruent or incongruent to the direction of gaze, which was irrelevant to the task. Each face was presented with a surgical facemask (i.e., Mask condition), without a mask (i.e., No-Mask condition), and with a patch that covered the same area occupied by the mask (i.e., control condition). The latter condition was introduced to allow us to exclude the possibility that a potential difference between the Mask and the No-Mask conditions was due to perceptual and spatial characteristics of having the mouth and part of the nose covered. In other words, in the control condition, the same face area, not visible in the Mask condition, was covered by a patch (with no intending protective meaning) to control for other spatial factors but leave the crucial eye region visible. Indeed, previous studies (e.g., Akiyama et al., 2008; Hayward and Ristic, 2015; Slessor et al., 2016) have shown that presenting just the eye region showing an averted gaze was enough to elicit the GCE. Therefore, our control condition as well as controlling for other perceptual factors allowed us to test whether the meaning of wearing a mask had a specific effect on gaze cueing.

Given the role of the mask in protecting ourselves and others from the spread of COVID-19, and building on the results of previous studies (e.g., Olivera-La Rosa et al., 2020), we considered the surgical mask as a positively valued object. For this reason, we hypothesized that participants could be more inclined to orient toward the direction of gaze of a person when this person is wearing a mask than when s/he is not wearing it, leading to a larger GCE in the Mask condition compared to the No-Mask condition and the Control condition. More specifically, we reasoned that observing someone who is wearing a facemask could lead us to orient our attention more in the direction of his/her gaze (thus to a greater GCE) than observing someone who is not wearing it as we may feel, for example, much more well-disposed towards those we do not perceive as a threat to our health. Alternatively, or as well, the facemask could lead to a greater GCE as the person wearing it could be perceived as more reliable than others thus deserving our trust.

As for the classic Simon effect, we hypothesized that the type of conditions (i.e., mask, no mask, control) should have a weaker effect, or no effect at all, since the classical Simon effect has not been reported to be affected by the participant's attitude towards the stimulus, or by social perception, since it does not require to take into account a shared spatial representation of the task. By adopting a horizontal left/right keypress response set we were allowed to explore whether any spatial interplay (due to processing of a spatial code in both tasks) occurred between the GCE and the stimulus–response correspondence, and whether it varies across the manipulated conditions. More specifically, we aimed at examining whether the conflict that originates from the Simon effect has an influence on the GCE. Indeed, as far as we know, there are only a few previous studies that employed an orthogonal manipulation of stimulus position and gaze direction and found the two effects being independent (Zorzi et al., 2003; see also Ricciardelli et al., 2007). However, these previous studies did not employ the classic gaze-cueing paradigm and used schematic eyes rather than realistic gaze stimuli.

In summary, this study aims at assessing whether the presence of a surgical mask on the face modifies the gaze cueing effect, and whether and how this form of social attention could be modulated by motor conflict (like the ones posited by Simon tasks). Understanding the mechanisms underlying the interaction between social attention and motor behavior is a timely and crucial issue. Since the COVID-19 global pandemic hugely impacted humans' social relations, it is important to understand whether the use of the face mask, useful to protect ourselves and prevent the spreading of the disease, has altered our perception and disposition towards the other.

Materials and methods

Participants

Data were collected from June 19, 2020, until December 8, 2020, between the first and second waves of the pandemic in Italy. We calculated the sample size required to achieve 80% power to detect a significant Congruency (i.e., GCE, congruent vs. incongruent) × Correspondence (i.e., Simon effect, corresponding vs. non-corresponding) × Condition (Mask, No-Mask, Control) interaction with the G*power 3.1 (Faul et al., 2007) software. With an effect size $f = 0.15$ (Cohen, 1988) and a correlation among repeated measures = 0.5, the power calculation yielded a recommended sample size of at least 42 participants.

A total of 40–60 undergraduate Italian students (40 females; 16 males; 7 left-handed; M age = 20.2 years; SD age = 2.5) from the University of Bologna participated as volunteers. All were naïve as to the purpose of the experiment. The study was conducted in accordance with the ethical standards laid down in the Declaration of Helsinki, and fulfilled the ethical standard procedure recommended by the Italian Association of Psychology (AIP). Written consent was obtained from all of them.

Apparatus and stimuli

We used the online behavioral science platform Gorilla (www.gorilla.sc; Anwyl-Irvine et al., 2020; for a critical overview of the online platform see Scerrati et al., 2021) to create and host the experiment. In order to minimize possible distractions, the participants were invited to carry out the experiment in a quiet place and to avoid manipulating objects during the entire task. In addition, we asked participants to close other background apps/programs and all browser windows except for that of the experiment. The automated procedure ensured that participants were all using computers, since no other devices were allowed (e.g., tablets, smartphones), and automatically rejected participants who took longer than 2 h to complete the task.

Stimuli were grayscale photographs (198 × 283 pixels) depicting 4 Caucasian young adults (2 females and 2 males) bearing a neutral expression. All photographs, selected from the Karolinska Directed Emotional Faces set (KDEF; Lundqvist et al., 1998), had a direct gaze and the versions with the averted gaze were taken from Ricciardelli et al. (2012, 2016), who already manipulated this aspect in their study starting from the same (identity faces: AF21 AF31 AM10 AM17). Informed consent for publication of identified images is available at https://kdef.se/home/using%20and%20publishing%20kdef%20and%20akdef.html.

Adobe Photoshop software was used to create a grayscale mask (129 × 122 pixel) and a patch (106 × 93 pixel), that were superimposed in the lower part of each face stimulus, to create the stimuli conditions Mask and Control, respectively. The No-Mask condition refers to face stimuli with no element superimposed. Thus, the final set of face stimuli consisted of 24 pictures: 4

different individuals (2 females and 2 males) × 2 gaze direction (left and right) × 3 conditions (Mask, No-Mask, and Control). An example of the stimuli used in the experiment is displayed in Figure 1.

Procedure

Each trial began with the presentation of a white fixation cross (23 × 23 pixel) in the center of a gray screen for 900 ms, followed by a central face with a direct gaze. After 900 ms, the same face appeared with an averted gaze (cue frame). After 200 ms, a white target letter (L or T, about 18 × 30 pixel, target frame) appeared to the left or right of the cue face, with equal probability. The target location could be spatially congruent or incongruent with the gaze direction and spatially corresponding or non-corresponding with the response location. The target frame remained visible until a response was provided (Figure 2; see Dalmaso et al., 2012; Ciardo et al., 2015 for a similar gaze-cueing procedure). The gaze direction was uninformative relative to the target location. Participants were instructed to maintain the fixation at the center of the screen and to respond according to the letter identity by using their right and left index fingers. Half of the participants were instructed to press a left key if the target was an "L" and a right key if the target was a "T" (respectively the "e" and "o" keys on a QWERTY keyboard without the numeric keypad or the "y" and "p" keys on a QWERTY keyboard with the numeric keypad). The other half of the participants responded using the opposite stimulus–response mapping. Instruction emphasized both speed and accuracy. No feedback was provided.

There were 24 trials for each combination of the following factors: congruence between gaze direction and target location (congruent vs. incongruent), correspondence between target location and response location (corresponding vs. non-corresponding) and conditions (Mask, No-Mask, Control). A total of 288 trials were presented pseudorandomly (i.e., same random order across participants) across three equal blocks of 96 trials each. A short rest was allowed between blocks. A practice session of 16 trials with only the No-Mask condition was given prior to the beginning of the experimental section.

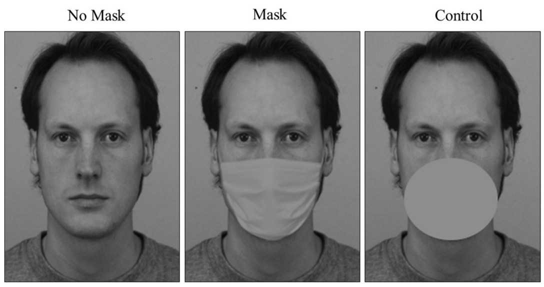

FIGURE 1
Example of the three conditions employed in the study: No Mask, Mask, and Control. Face stimuli were selected from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist et al., 1998). The identity of the face depicted is AM10 NEU.

Results

Practice trials, errors (3.9% of the total trials) and trials with RTs faster (0.1%) or slower (3.4%) than 2 SD from the individual RT average were not included in the analysis. One participant with RTs average > 3,000 ms was excluded from the sample. The analysis was conducted on 55 participants (40 females, 15 males, 7 left-handed, Mean age = 20.2 years, SD age = 2.5).

The Kolmogorov–Smirnov and Shapiro–Wilk tests indicated that the mean RTs do not follow normal distribution [D(55) = 0.136; $p = 0.013$; W(55) = 0.925, $p = 0.002$]. However, since Skewness and Kurtosis indexes of our dependent variables indicate a slight or moderate departure from normality distribution (see Supplementary Materials for a table with all values), we decided to analyze our data with parametric statistics (see George and Mallery, 2010; Blanca et al., 2017; Field and Wilcox, 2017). A repeated-measures ANOVA was conducted on RTs with *Congruence* (congruent vs. incongruent), *Correspondence* (corresponding vs. non-corresponding), and *Condition* (Mask, No-Mask, Control), as within-subjects factors.

The analysis revealed a significant main effect of *Congruence* [$F(1, 54) = 16.364$, $MSE = 32{,}382{,}325$, $p < 0.001$, $\eta_p^2 = 0.233$], indicating faster RTs for congruent (M = 595 ms) than incongruent (M = 609 ms) trials, resulting in an overall GCE of 14 ms. There was also a main effect of *Correspondence* [$F(1, 54) = 35{,}316$, $MSE = 85{,}577{,}699$, $p < 0.001$, $\eta_p^2 = 0.395$], showing faster RTs on corresponding (M = 591 ms) than non-corresponding (M = 613 ms) trials, resulting in an overall Simon effect of 22 ms. The main effect of *Condition* did not reach significance [$F(1, 54) = 0.652$, $MSE = 637{,}446$, $p = 0.511$, $\eta_p^2 = 0.012$]. Importantly, there was a significant three-way interaction between *Congruence*, *Correspondence*, and *Condition* [$F(1, 54) = 5{,}537$, $MSE = 6{,}309{,}092$, $p = 0.007$, $\eta_p^2 = 0.093$], indicating that the GCE differed across conditions and was influenced by correspondence. We found a significant GCE in the Mask condition for Corresponding trials, and in the Control condition for Non-corresponding trials, and non-significant GCE in the No-Mask condition for both Corresponding and Non-Corresponding trials. Specifically, paired sample t-tests showed that for the Mask condition the GCE was 31 ms for the Corresponding trials and 5 ms for the Non-Corresponding trials; for the Control condition the GCE was 5 ms for the Corresponding trials and 19 ms for the Non-Corresponding trials; finally for the No-Mask condition the GCE was 12 ms for the Corresponding trials and 12 ms for the Non-Corresponding trials. See Figure 3 and Table 1.

Moreover, we explored whether stimulus–response location (i.e., Simon effect) is influenced by the GCE across conditions. In line with our expectations, we found a strong Simon effect in all experimental conditions regardless of congruence, except for

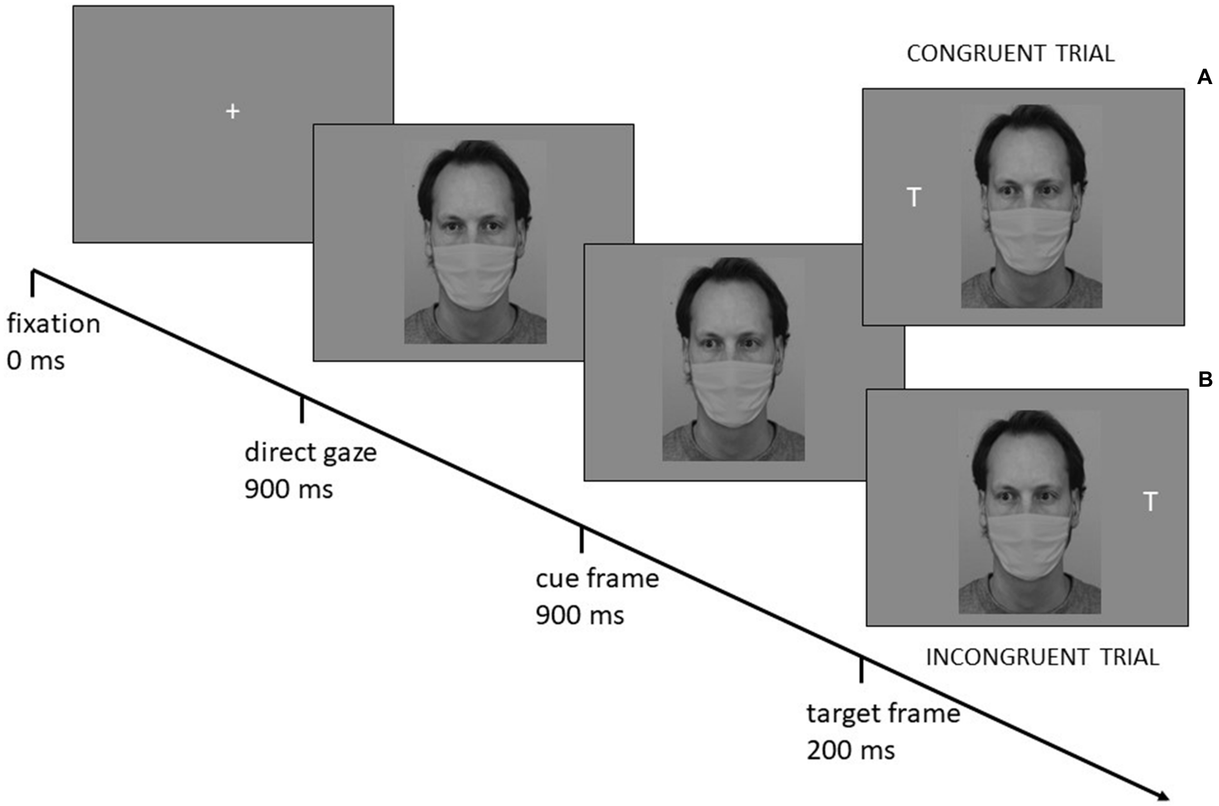

FIGURE 2
Illustration of the gaze-cueing procedure depicting examples of Mask condition stimuli (not drawn to scale) and sequence of events for a congruent trial (top) and an incongruent trial (bottom).

non-significant Simon effect in the Mask condition for incongruent trials. See Table 2. No other main effects or interactions were significant ($F_s < 1$).

Discussion

The spread of the COVID-19 pandemic has changed our ordinary social behavior, influencing our relationships with others. As a consequence, specific social attentional processes might be more sensitive to important stimuli in the environment aimed at preventing infection. Previous research has extensively investigated attentional processing, showing that both spatial information and social factors are automatically encoded and affect the recognition of perceptual stimuli. However, a growing body of evidence has shown that standard attentional processes could be modulated by the current task and by context-relevant information (e.g., D'Ascenzo et al., 2022; for a discussion, see Lebois et al., 2015).

In the present study, we tested the impact of the facemask adopted to prevent the spread of COVID-19 on social attention through a gaze-cueing paradigm, where stimulus–response correspondence was also investigated. The face stimuli were presented to participants in three different conditions: without the surgical mask (No-Mask), with the surgical mask superimposed on the lower portion of the face (Mask), and with a patch that covered the same area occupied by the mask (Control).

Our results showed an overall GCE across conditions, indicating faster responses when the target was presented in a location congruent to the gaze direction, compared to when it was presented in an incongruent location. This result is consistent with the previous literature on GCE (for a review, see Dalmaso et al., 2020), confirming the role of others' gaze direction as a social cue to orient attention. In addition, an overall Simon effect emerged, thus when the target was in the same location as the response key position participants were faster than when it was in the opposite location.

Interestingly, the GCE was modulated by condition only when the correspondence between target location and response position was taken into account. Specifically, when target location and response position were on the same side, thus no motor conflict emerged (i.e., corresponding trial), a GCE was evident in the Mask condition and approached significance in the No-Mask condition. In contrast, when target and response were in opposite locations and a motor conflict emerged (i.e., non-corresponding trial), a GCE was found in the Control condition and again approached significance in the No-Mask condition.

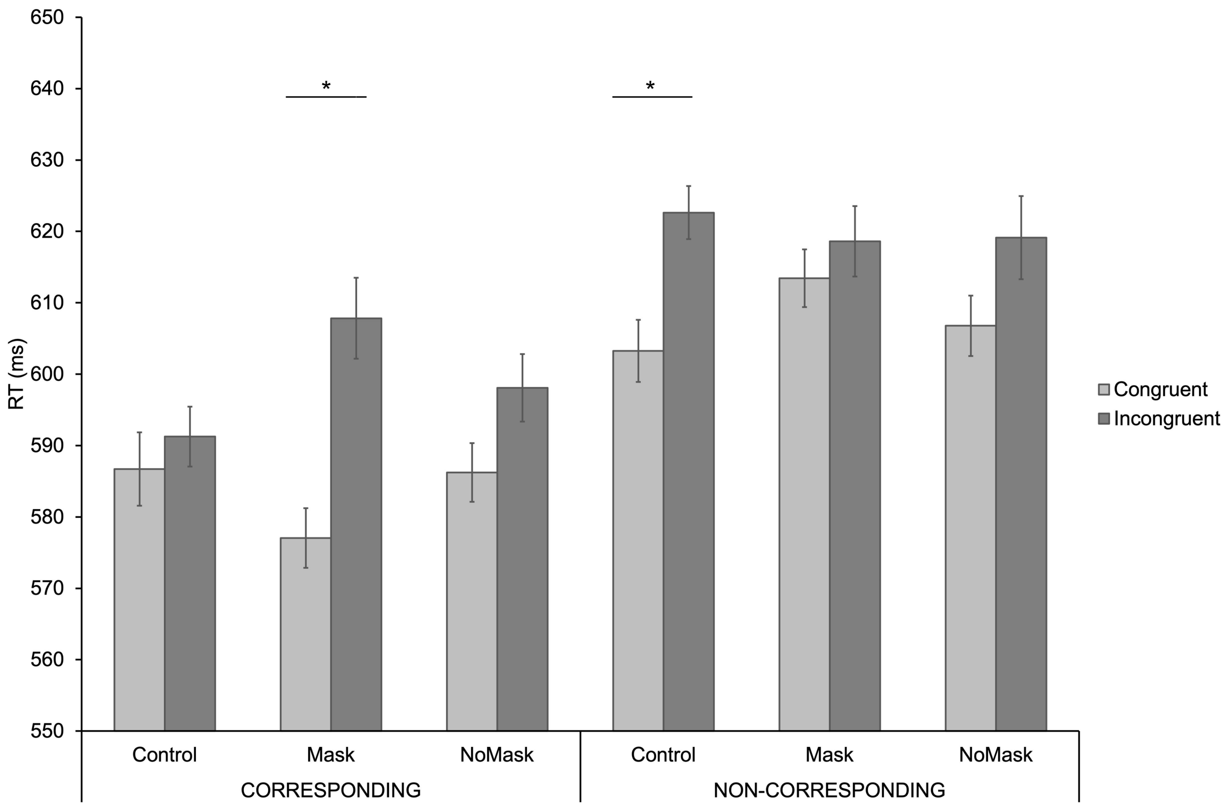

FIGURE 3
Mean reaction times (RTs) as a function of Condition and Congruence for Corresponding (leftmost panel) and Non-corresponding trials (rightmost panel). Error bars indicate standard errors of the mean adjusted for within-participants designs (Loftus and Masson, 1994). Asterisks denote significant differences.

TABLE 1 Paired simple t-test comparing GCE effect (i.e., Incongruent vs. Congruent trials) in Simon Non-corresponding and Corresponding trials for each experimental condition (i.e., Control, Mask, No-Mask).

Condition					95% confidence interval					
		GCE (ms)	SD	SE	Lower	Upper	*t*	df	*p*	Cohen's *d*
Control	Simon corresponding	5	47.2	6.4	−8.2	17.3	0.716	54	0.477	0.26
	Simon non-corresponding	19	45.2	6.1	7.1	31.6	3.177	54	0.002	0.05
Mask	Simon corresponding	31	63.5	8.6	13.6	47.9	3.592	54	0.001	0.04
	Simon non-corresponding	5	52.2	7.0	−9.0	19.3	0.734	54	0.466	0.19
No-Mask	Simon corresponding	12	48.9	6.6	−1.4	25.1	1.797	54	0.078	0.11
	Simon non-corresponding	12	46.2	6.2	−0.1	24.8	1.982	54	0.053	0.10

Therefore, contrary to our initial predictions, the pattern of results was more complex and partially unexpected. However, the goodness of the experimental design adopted in the present study is suggested by the finding that in the No-Mask condition the classical gaze-cueing effect numerically emerged and did not interact with the Simon effect; thus, this result is in the same direction as those reported in previous studies (e.g., Dalmaso et al., 2012, 2014). Importantly, it is worth noting that in the present study the experiment was administered online. Web-based experiments may add noise to the data compared to the classical lab-based studies in which the experimental setting is more controlled (Sauter et al., 2020; see also Scerrati et al., 2021). Nevertheless, the pattern of the data collected online was in line with the classical gaze-cueing effect since it showed faster reaction time for congruent than incongruent conditions, thus suggesting the reliability of the study. Interestingly, our results only partially replicated evidence coming from a recent study by Dalmaso et al. (2021); published after our data collection was ended and a first version of the paper was drafted. Specifically, the authors explored the impact of face masks on social attention using a standard

TABLE 2 Paired simple t-test comparing Simon effect (i.e., Non-corresponding vs. Corresponding trials) in GCE Incongruent and congruent trials for each experimental condition (i.e., Control, Mask, No-Mask).

Condition					95% confidence interval					
		SE (ms)	SD	SE	Lower	Upper	*t*	df	*p*	Cohen' *d*
Control	GCE congruent	17	51.2	6.9	2.7	30.4	2.397	54	0.020	0.15
	GCE incongruent	31	45.1	6.1	19.2	43.6	5.161	54	0.000	0.29
Mask	GCE congruent	36	40.5	5.5	25.4	47.3	6.667	54	0.000	0.35
	GCE incongruent	11	44.7	6	−1.3	22.9	1.79	54	0.079	0.09
No-Mask	GCE congruent	21	52.5	7.1	6.3	34.7	2.9	54	0.005	0.18
	GCE incongruent	21	67.1	9	2.9	39.2	2.324	54	0.024	0.18

gaze-cueing task and found that the GCE is not altered as a function of mask condition, that is, a reliable GCE emerged either when stimuli were embedded in faces wearing a mask or not (i.e., Mask and No-Mask condition). However, differently from Dalmaso et al.'s study, we introduced a control condition (i.e., a patch covering the same face area obscured by surgical masks) and the stimulus–response correspondence (i.e., Simon effect) has been also analyzed. Therefore, a direct comparison between the two studies is not appropriate and it would be misleading.

The novelty of our results concerns the Mask and Control conditions in which we found a significant interaction between the GCE and the Simon effect but in opposite directions. Specifically, in the Mask condition, the GCE emerged only in corresponding trials, whereas in the Control condition, the GCE emerged only in non-corresponding trials. This pattern was unpredicted and can be explained by considering how the observer perceived the face covered either by a mask or a patch.

In the case of the Mask condition, there is an interaction between attentional (gaze cueing) and visual motor processes (Simon effect). In keeping with our original hypothesis, the person who is wearing a facemask might be perceived as "trustworthy" (though see Biermann et al., 2021; Malik et al., 2021 for a different interpretation) and this can lead the observer to direct his/her attention in the same direction as the face-masked gaze and not be afraid of approaching him/her. This can explain why in corresponding trials, i.e., those that facilitate action, the GCE emerges and is enhanced; instead, in non-corresponding trials, i.e., those that do not facilitate action, the GCE is inhibited or reduced.

In the case of the Control condition, the face obscured by a patch could likely appear bizarre and suspicious; thus, the seen face might be perceived as "untrustworthy" and potentially dangerous. In this condition, the observer can be inclined to move away from such a face, still monitoring it and paying attention to his/her gaze direction. This can explain the interaction between the gaze-cueing and Simon effect, resulting in an enhancement of the GCE in non-corresponding trials when a patch appears on the face. Indeed, there is evidence that perceiving angry or fearful faces leads to a greater GCE effect than neutral or positive stimuli (e.g., Bayless et al., 2011; Kuhn and Tipples, 2011; Lassalle and Itier, 2013; Pecchinenda and Petrucci, 2016; Carraro et al., 2017; Chen et al., 2021), suggesting that threatening stimuli potentiate automatic orienting to eye gaze.

Our data seem also to be in line with the assumption underlying the conflict monitoring theory (Botvinick et al., 2001), according to which a detected conflict determines an aversive signal that leads to avoidance learning, generating a negative value (Botvinick, 2007; see also Botvinick et al., 2001, 2004). This proposal was supported by several behavioral studies that showed how cognitive conflicts appear to be experienced as aversive events (Dreisbach and Fischer, 2012; Schouppe et al., 2012; see Dreisbach and Fischer, 2015 for review). Indeed, the corresponding trials show a GCE in the Mask condition as the absence of a cognitive conflict together with the presence of the mask on the cueing face may have strengthened participants' approach behavior (thus facilitating joint orienting). In other words, the mask may have made participants well-disposed towards those people they do not perceive as a threat to their health, encouraging them to orient their attention toward their gaze direction. Therefore at the same time, the absence of a cognitive conflict in the corresponding conditions may have enhanced this favorable behavior, which may have been prevented, instead, in the non-corresponding condition where a conflict emerges (avoidance).

In addition, our findings are in line with previous studies showing that the magnitude of the gaze cueing effect can be modulated by motor information, and sometimes even reversed (e.g., Nummenmaa et al., 2009; Ueda and Kitazaki, 2013). Evidence has been reported that individuals use others' gaze and head direction not only as a social cue to orient their own attention but also for inferring movement paths that can result in avoidance behaviors. For example, Nummenmaa et al. (2009) conducted an eye-tracking experiment in which participants observed a simulated scenario in which a pedestrian walked directly toward them, and were asked to indicate the direction in which they would orient to skirt the oncoming person by pressing a left or right response button. The authors found that responses were faster for gaze-incongruent than for gaze-congruent trials (i.e., reversed gaze-effect). That is, participants shifted their attention away from the perceived gaze direction to prevent a collision, and tended to fixate longer in the direction of their upcoming movement (i.e., the opposite side the oncoming person was looking at). Crucially, this reverse effect was faster in manual than saccadic responses, indicating that the evaluation of others' goals affects at first stage one's own actions and then attention direction. Similar results were obtained by Ueda and Kitazaki (2013) in a study in which participants used mouse movement to avoid collision with a virtual walker who rotated his head leftward or rightward. Specifically, their results showed that when the walker's head changed direction, participants moved the mouse to the opposite side, thus activating an appropriate movement for collision avoidance. Taken together, these studies suggest that orienting social attention is not always automatically triggered by gaze direction or head orientation, rather further socio-cognitive evaluations related to context can lead to avoidance behaviors (e.g., "reverse" gaze cueing). Thus, gaze direction not only allows us to make inferences about others' behaviors but is also a useful source of information for our own movement planning.

Interestingly, studies have shown that under certain conditions, attention and social perception influence motor processes. For example, Capellini et al. (2016) investigated the influence of social threat on motor responses using an action observation paradigm in which RTs and the computer mouse trajectories were recorded. The authors found that threatening situations, elicited by an outgroup member and by contextual cues, enhance visual monitoring and interfere with motor responses required by the task. Specifically, when participants faced a stereotypical aggressive outgroup member moving toward a weapon, a delay in response to a target stimulus occurred, suggesting that people allocate their visual attention to this agent and freeze their motor reactions because the context can become potentially menacing.

Similarly, in our study we found that the gaze direction contributes to guiding our own movement in terms of motor responses, depending on social-contextual factors. Face stimuli perceived as safe (i.e., wearing the mask) and that does not expose us to potential risk generate a marked GCE when motor conflict is absent (i.e., corresponding trials) and an approaching behavior is potentially favored, while face stimuli perceived as untrustworthy (i.e., covered by a patch) generates a marked GCE when motor conflict is present (i.e., non-corresponding trials) thus favoring a potential aversive behavior. Interestingly, this is supported by the fact that, when the face was not covered at all (i.e., No-Mask condition) thus conveying no clear or strong information about the social and affective valence of the seen person, the GCE was not affected by motor correspondence, indeed it emerged both in the absence and in the presence of motor conflict. More investigation is required to corroborate our results and to deepen the underpinning mechanisms of the interaction between the GCE and the Simon effect that emerged in the present work. A possible limitation in generalizing our results is that they consider a sample composed of mainly female participants, since previous studies have indicated that females present higher gaze cueing effects and higher sensibility to social cues (e.g., Ciardo et al., 2015; see also Mazzuca et al., 2020).

To conclude, this study provides preliminary evidence of an interaction between gaze-cueing effect and stimulus–response correspondence effect, showing a larger GCE in the corresponding condition for face associated with positive valence that can, thus, enhance potential approaching behavior, and in the non-corresponding condition for face associated to negative valence that can, instead, lead to potential avoidance behavior. Further studies could investigate whether other social characteristics of faces, such as emotions, race, or social status, lead to similar effects. In particular, using a similar paradigm manipulating the social characteristics of the cueing faces could be very informative. For example, using cueing faces validated for trust would be useful to corroborate the hypothesis that the level of trustworthiness of a human face may drive the interaction between our social attention and motor behavior.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics committee of the University of Bologna. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

CV: conceptualization, methodology, software, data collection, data analyses, and writing—original draft preparation. SD'A: conceptualization, methodology, data analyses, and writing—reviewing and editing. ES: conceptualization, methodology, and writing—reviewing and editing. PR: conceptualization, methodology, writing—reviewing and editing, and supervision. RN: conceptualization, methodology, and supervision. LL: conceptualization, methodology, writing—reviewing and editing, and supervision. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.923558/full#supplementary-material

References

Akiyama, T., Kato, M., Muramatsu, T., Maeda, T., Hara, T., and Kashima, H. (2008). Gaze-triggered orienting is reduced in chronic schizophrenia. *Psychiatry Res.* 158, 287–296. doi: 10.1016/j.psychres.2006.12.004

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., and Evershed, J. K. (2020). Gorilla in our midst: an online behavioral experiment builder. *Behav. Res. Methods* 52, 388–407. doi: 10.3758/s13428-019-01237-x

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001). The "Reading the mind in the eyes" test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *J. Child Psychol. Psychiatry Allied Discip.* 42, 241–251. doi: 10.1111/1469-7610.00715

Baroni, G., Pellicano, A., Lugli, L., Nicoletti, R., and Proctor, R. W. (2012). Influence of temporal overlap on time course of The Simon effect. *Exp. Psychol.* 59, 88–98. doi: 10.1027/1618-3169/a000130

Bayless, S. J., Glover, M., Taylor, M. J., and Itier, R. J. (2011). Is it in the eyes? Dissociating the role of emotion and perceptual features of emotionally expressive faces in modulating orienting to eye gaze. *Vis. Cogn.* 19, 483–510. doi: 10.1080/13506285.2011.552895

Bayliss, A. P., di Pellegrino, G., and Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention. *Q. J. Exp. Psychol.* 58, 631–650. doi: 10.1080/02724980443000124

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the COVID-19 pandemic in Germany: an experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Blanca, MJ, Alarcón, R, Arnau, J, Bono, R, and Bendayan, R. (2017). Non-normal data: is ANOVA still a valid option? *Psicothema.* 29:552–557. doi: 10.7334/psicothema2016.383

Bogardus, E. S. (1933). A social distance scale. *Sociol. Soc. Res.* 17, 265–271.

Bonifacci, P., Ricciardelli, P., Lugli, L., and Pellicano, A. (2008). Emotional attention: effects of emotion and gaze direction on overt orienting of attention. *Cogn. Process.* 9, 127–135. doi: 10.1007/s10339-007-0198-3

Botvinick, M. M. (2007). Conflict monitoring and decision making: reconciling two perspectives on anterior cingulate function. *Cogn. Affect. Behav. Neurosci.* 7, 356–366. doi: 10.3758/CABN.7.4.356

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., and Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychol. Rev.* 108, 624–652. doi: 10.1037/0033-295X.108.3.624

Botvinick, M. M., Cohen, J. D., and Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: an update. *Trends Cogn. Sci.* 8, 539–546. doi: 10.1016/j.tics.2004.10.003

Capellini, R., Sacchi, S., Ricciardelli, P., and Actis-Grosso, R. (2016). Social threat and motor resonance: when a menacing outgroup delays motor response. *Front. Psychol.* 7:1697. doi: 10.3389/fpsyg.2016.01697

Capozzi, F., and Ristic, J. (2018). How attention gates social interactions. *Ann. N. Y. Acad. Sci.* 1426, 179–198. doi: 10.1111/nyas.13854

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11, 1–8. doi: 10.3389/fpsyg.2020.566886

Carbon, C.-C., and Serrano, M. (2021). The impact of face masks on the emotional reading abilities of children—a lesson from a joint school–university project. *i-Perception* 12, 1–17. doi: 10.1177/20416695211038265

Carragher, D. J., and Hancock, P. J. B. (2020). Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cogn. Res. Princ. Implic.* 5:59. doi: 10.1186/s41235-020-00258-x

Carraro, L., Dalmaso, M., Castelli, L., Galfano, G., Bobbio, A., and Mantovani, G. (2017). The appeal of the devil's eye: social evaluation affects social attention. *Cogn. Process.* 18, 97–103. doi: 10.1007/s10339-016-0785-2

Chen, Z., McCrackin, S. D., Morgan, A., and Itier, R. J. (2021). The gaze cueing effect and its enhancement by facial expressions are impacted by task demands: direct comparison of target localization and discrimination tasks. *Front. Psychol.* 12:618606. doi: 10.3389/fpsyg.2021.618606

Ciardo, F., Lugli, L., Nicoletti, R., Rubichi, S., and Iani, C. (2016). Action-space coding in social contexts. *Sci. Rep.* 6:22673. doi: 10.1038/srep22673

Ciardo, F, Marino, B.F, Actis-Grosso, R, Rossetti, A, and Ricciardelli, P. (2014). Face age modulates gaze following in young adults. *Sci Rep. Apr* 4:4746. doi: 10.1038/srep04746.

Ciardo, F., Marino, B. F. M., De Angelis, J., Actis-Grosso, R., and Ricciardelli, P. (2021). Social categorization and joint attention: interacting effects of age, sex, and social status. *Acta Psychol.* 212:103223. doi: 10.1016/j.actpsy.2020.103223

Ciardo, F., Ricciardelli, P., Lugli, L., Rubichi, S., and Iani, C. (2015). Eyes keep watch over you! Competition enhances joint attention in females. *Acta Psychol.* 160, 170–177. doi: 10.1016/j.actpsy.2015.07.013

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences. 2nd Edn.* Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

D'Ascenzo, S., Lugli, L., Baroni, G., Guidotti, R., Rubichi, S., Iani, C., et al. (2018). Visual versus auditory Simon effect: a behavioural and physiological investigation. *Q. J. Exp. Psychol.* 71, 917–930. doi: 10.1080/17470218.2017.1307429

D'Ascenzo, S., Lugli, L., Nicoletti, R., and Umiltà, C. (2020). Practice effects vs. transfer effects in the Simon task. *Psychol. Res.* 85, 1–15. doi: 10.1007/s00426-020-01386-1

D'Ascenzo, S., Scerrati, E., Villani, C., Galatolo, R., Lugli, L., and Nicoletti, R. (2022). Does social distancing affect the processing of brand logos? *Brain Behav.* 12:e2501. doi: 10.1002/brb3.2501

Dalmaso, M., Castelli, L., and Galfano, G. (2020). Social modulators of gaze-mediated orienting of attention: a review. *Psychon. Bull. Rev.* 27, 833–855. doi: 10.3758/s13423-020-01730-x

Dalmaso, M., Galfano, G., Coricelli, C., and Castelli, L. (2014). Temporal dynamics underlying the modulation of social status on social attention. *PLoS One* 9:e93139. doi: 10.1371/journal.pone.0093139

Dalmaso, M., Pavan, G., Castelli, L., and Galfano, G. (2012). Social status gates social attention in humans. *Biol. Lett.* 8, 450–452. doi: 10.1098/rsbl.2011.0881

Dalmaso, M., Zhang, X., Galfano, G., and Castelli, L. (2021). Face masks do not alter gaze cueing of attention: evidence from the COVID-19 pandemic. *i-Perception* 12:20416695211058480. doi: 10.1177/20416695211058480

De Jong, R., Liang, C.-C., and Lauber, E. (1994). Conditional and unconditional automaticity: a dual-process model of effects of spatial stimulus–response correspondence. *J. Exp. Psychol. Hum. Percept. Perform.* 20, 731–750. doi: 10.1037/0096-1523.20.4.731

Deaner, R. O., Shepherd, S. V., and Platt, M. L. (2007). Familiarity accentuates gaze cuing in women but not men. *Biol. Lett.* 3, 65–68. doi: 10.1098/rsbl.2006.0564

Dolk, T., Hommel, B., Colzato, L. S., Schütz-Bosbach, S., Prinz, W., and Liepelt, R. (2014). The joint Simon effect: a review and theoretical integration. *Front. Psychol.* 5:974. doi: 10.3389/fpsyg.2014.00974

Dreisbach, G., and Fischer, R. (2012). Conflicts as aversive signals. *Brain Cogn.* 78, 94–98. doi: 10.1016/j.bandc.2011.12.003

Dreisbach, G., and Fischer, R. (2015). Conflicts as aversive signals for control adaptation. *Curr. Dir. Psychol. Sci.* 24, 255–260. doi: 10.1177/0963721415569569

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., and Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Vis. Cogn.* 6, 509–540. doi: 10.1080/135062899394920

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/bf03193146

Field, A. P., and Wilcox, R. R. (2017). Robust statistical methods: a primer for clinical psychology and experimental psychopathology researchers. *Behav. Res. Ther.* 98, 19–38. doi: 10.1016/j.brat.2017.05.013

Freud, E., Stajduhar, A., Rosenbaum, R. S., Avidan, G., and Ganel, T. (2020). The COVID-19 pandemic masks the way people perceive faces. *Sci. Rep.* 10:22344. doi: 10.1038/s41598-020-78986-9

Friesen, C. K., and Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychon. Bull. Rev.* 5, 490–495. doi: 10.3758/BF03208827

Frischen, A., Bayliss, A. P., and Tipper, S. P. (2007). Gaze cueing of attention: visual attention, social cognition, and individual differences. *Psychol. Bull.* 133, 694–724. doi: 10.1037/0033-2909.133.4.694

George, D., and Mallery, M. (2010). *SPSS for Windows Step by Step: A Simple Guide and Reference, 17.0 Update* (*10a ed.*). Boston: Pearson.

Grossmann, T. (2017). The eyes as windows Into other minds: an integrative perspective. *Perspect. Psychol. Sci.* 12, 107–121. doi: 10.1177/1745691616654457

Hayward, D. A., and Ristic, J. (2015). Exposing the cuing task: the case of gaze and arrow cues. *Atten. Percept. Psychophys.* 77, 1088–1104. doi: 10.3758/s13414-015-0877-6

Hommel, B., Colzato, L. S., and van den Wildenberg, W. P. M. (2009). How social are task representations. *Psychol. Sci.* 20, 794–798. doi: 10.1111/j.1467-9280.2009.02367.x

Iani, C., Anelli, F., Nicoletti, R., Arcuri, L., and Rubichi, S. (2011). The role of group membership on the modulation of joint action. *Exp. Brain Res.* 211, 439–445. doi: 10.1007/s00221-011-2651-x

Iani, C., Anelli, F., Nicoletti, R., and Rubichi, S. (2014). The carry-over effect of competition in task-sharing: evidence from the joint Simon task. *PLoS One* 9:e97991. doi: 10.1371/journal.pone.009799

Iani, C., Ciardo, F., Panajoli, S., Lugli, L., and Rubichi, S. (2021). The role of the co-actor's response reachability in the joint Simon effect: remapping of working space by tool use. *Psychol. Res.* 85, 521–532. doi: 10.1007/s00426-019-01271-6

Jones, B. C., DeBruine, L. M., Main, J. C., Little, A. C., Welling, L. L., Feinberg, D. R., et al. (2010). Facial cues of dominance modulate the short-term gaze-cuing effect in human observers. *Proc. R. Soc. B Biol. Sci.* 277, 617–624. doi: 10.1098/rspb.2009.1575

Kornblum, S., Hasbroucq, T., and Osman, A. (1990). Dimensional overlap: cognitive basis for stimulus-response compatibility: a model and taxonomy. *Psychol. Rev.* 97, 253–270. doi: 10.1037/0033-295X.97.2.253

Kuhbandner, C., Pekrun, R., and Maier, M. A. (2010). The role of positive and negative affect in the "mirroring" of other persons' actions. *Cognit. Emot.* 24, 1182–1190. doi: 10.1080/02699930903119196

Kuhn, G., and Tipples, J. (2011). Increased gaze following for fearful faces. It depends on what you're looking for! *Psychon. Bull. Rev.* 18, 89–95. doi: 10.3758/s13423-010-0033-1

Langton, S. R. H., and Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Vis. Cogn.* 6, 541–567. doi: 10.1080/135062899394939

Lassalle, A., and Itier, R. J. (2013). Fearful, surprised, happy, and angry facial expressions modulate gaze-oriented attention: behavioral and ERP evidence. *Soc. Neurosci.* 8, 583–600. doi: 10.1080/17470919.2013.835750

Lebois, L. A., Wilson-Mendenhall, C. D., and Barsalou, L. W. (2015). Putting everything in 985 context. *Cogn. Sci.* 39, 1987–1995. doi: 10.1111/cogs.12295

Liang, M., Gao, L., Cheng, C., Zhou, Q., Uy, J. P., Heiner, K., et al. (2020). Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis. *Travel Med. Infect. Dis.* 36:101751. doi: 10.1016/j.tmaid.2020.101751

Loftus, G. R., and Masson, M. E. (1994). Using confidence intervals in within-subject designs. *Psychon. Bull. Rev.* 1, 476–490.

Lugli, L., Baroni, G., Nicoletti, R., and Umiltà, C. A. (2016). The Simon effect with saccadic eye movements. *Exp. Psychol.* 63, 107–116. doi: 10.1027/1618-3169/a000319

Lugli, L., D'Ascenzo, S., Nicoletti, R., and Umiltà, C. (2017). The role of visual distractors in the Simon effect. *Exp. Psychol.* 64, 387–397. doi: 10.1027/1618-3169/a000382

Lugli, L., Iani, C., Milanese, N., Sebanz, N., and Rubichi, S. (2015). Spatial parameters at the basis of social transfer of learning. *J. Exp. Psychol. Hum. Percept. Perform.* 41, 840–849. doi: 10.1037/xhp0000047

Lugli, L., Iani, C., Nicoletti, R., and Rubichi, S. (2013). Emergence of the go/no-go Simon effect by means of practice and mixing paradigms. *Acta Psychol.* 144, 19–24. doi: 10.1016/j.actpsy.2013.04.021

Lundqvist, D., Flykt, A., and Öhman, A. (1998). The Karolinska Directed Emotional Faces*KDEF [CD ROM]. Department of Clinical Neuroscience, Psychology Section, Karolinska Institute.

Malik, S., Mihm, B., and Reichelt, M. (2021). The impact of face masks on interpersonal trust in times of COVID-19. *Sci. Rep.* 11, 1–9. doi: 10.1038/s41598-021-96500-7

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11, 1–14. doi: 10.1038/s41598-021-84806-5

Mattavelli, G., Romano, D., Young, A. W., and Ricciardelli, P. (2021). The interplay between gaze cueing and facial trait impressions. *Q. J. Exp. Psychol.* 74, 1642–1655. doi: 10.1177/17470218211007791

Mazzuca, C., Majid, A., Lugli, L., Nicoletti, R., and Borghi, A. M. (2020). Gender is a multifaceted concept: evidence that specific life experiences differentially shape the concept of gender. *Lang. Cogn.* 12, 649–678.

Nestor, M. S., Fischer, D., and Arnold, D. (2020). "Masking" our emotions: botulinum toxin, facial expression, and well-being in the age of COVID-19. *J. Cosmet. Dermatol.* 19, 2154–2160. doi: 10.1111/jocd.13569

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L. H., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Nummenmaa, L., Hyönä, J., and Hietanen, J. K. (2009). I'll walk this way: eyes reveal the direction of locomotion and make passersby look and go the other way. *Psychol. Sci.* 20, 1454–1458. doi: 10.1111/j.1467-9280.2009.02464.x

Oldmeadow, J. A., and Koch, C. (2021). Effects of face masks on person perception. *Perception* 50, 876–889. doi: 10.1177/03010066211045172

Olivera-La Rosa, A., Chuquichambi, E. G., and Ingram, G. P. (2020). Keep your (social) distance: pathogen concerns and social perception in the time of COVID-19. *Personal. Individ. Differ.* 166:110200. doi: 10.1016/j.paid.2020.110200

Parada-Fernández, P., Herrero-Fernández, D., Jorge, R., and Comesaña, P. (2022). Wearing mask hinders emotion recognition, but enhances perception of attractiveness. *Personal. Individ. Differ.* 184:111195. doi: 10.1016/j.paid.2021.111195

Pavan, G., Dalmaso, M., Galfano, G., and Castelli, L. (2011). Racial group membership is associated to gaze-mediated orienting in Italy. *PLoS One* 6:e25608. doi: 10.1371/journal.pone.0025608

Pavlova, M. A., and Sokolov, A. A. (2022). Reading covered faces. *Cereb. Cortex* 32, 249–265. doi: 10.1093/cercor/bhab311

Pecchinenda, A., and Petrucci, M. (2016). Emotion unchained: facial expression modulates gaze cueing under cognitive load. *PLoS One* 11:e0168111. doi: 10.1371/journal.pone.0168111

Pellicano, A., Lugli, L., Baroni, G., and Nicoletti, R. (2009). The Simon effect with conventional signals: a time-course analysis. *Exp. Psychol.* 56, 219–227. doi: 10.1027/1618-3169.56.4.219

Pellicano, A., Lugli, L., Binkofski, F., Rubichi, S., Iani, C., and Nicoletti, R. (2019). The unimanual handle-to-hand correspondence effect: evidence for a location coding account. *Psychol. Res.* 83, 1383–1399. doi: 10.1007/s00426-018-1009-4

Ricciardelli, P., Bonfiglioli, C., Iani, C., Rubichi, S., and Nicoletti, R. (2007). Spatial coding and central patterns: is there something special about the eyes? *Can. J. Exp. Psychol.* 61, 79–90. doi: 10.1037/cjep2007009

Ricciardelli, P., Iani, C., Lugli, L., Pellicano, A., and Nicoletti, R. (2012). Gaze direction and facial expressions exert combined but different effects on attentional resources. *Cognit. Emot.* 26, 1134–1142. doi: 10.1080/02699931.2011.638907

Ricciardelli, P., Lugli, L., Pellicano, A., Iani, C., and Nicoletti, R. (2016). Interactive effects between gaze direction and facial expression on attentional resources deployment: the task instruction and context matter. *Sci. Rep.* 6:21706. doi: 10.1038/srep21706

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Rubichi, S., Vu, K., Nicoletti, R., and Proctor, R. (2006). Two-dimensional spatial coding. *Psychon. Bull. Rev.* 13, 201–216. doi: 10.3758/BF03193832

Ruissen, M. I., and de Bruijn, E. R. A. (2016). Competitive game play attenuates self-other integration during joint task performance. *Front. Psychol.* 7:274. doi: 10.3389/fpsyg.2016.0027

Sauter, M, Draschkow, D, and Mack, W. (2020). Building, hosting and recruiting: a brief introduction to running behavioral experiments online. *Brain Sci*. 10:251. doi: 10.3390/brainsci10040251.

Scerrati, E., Lugli, L., Nicoletti, R., and Umiltà, C. (2017). Comparing stroop-like and Simon effects on perceptual features. *Sci. Rep.* 7:17815. doi: 10.1038/s41598-017-18185-1

Scerrati, E., Marzola, G., Villani, C., Lugli, L., and D'Ascenzo, S., (2021). Nuovi scenari per gli esperimenti in psicologia: la modalità online. (Giornale Italiano di Psicologia), 843–863.

Schouppe, N., De Houwer, J., Richard Ridderinkhof, K., and Notebaert, W. (2012). Conflict: run! Reduced stroop interference with avoidance responses. *Q. J. Exp. Psychol.* 65, 1052–1058. doi: 10.1080/17470218.2012.685080

Sebanz, N., Knoblich, G., and Prinz, W. (2003). Representing others' actions: just like one's own? *Cognition* 88, B11–B21. doi: 10.1016/S0010-0277(03)00043-X

Simon, J. R. (1969). Reactions toward the source of stimulation. *J. Exp. Psychol.* 81, 174–176. doi: 10.1037/h0027448

Simon, J. R. (1990). "The effects of an irrelevant directional cue on human information processing," in *Stimulus–Response Compatibility: An Integrated Perspective*. eds. R. W. Proctor and T. G. Reeve (Amsterdam: Elsevier), 31–86.

Simon, J. R., and Rudell, A. P. (1967). Auditory S–R compatibility: the effect of an irrelevant cue on information processing. *J. Appl. Psychol.* 51, 300–304. doi: 10.1037/h0020586

Slessor, G., Laird, G., Phillips, L. H., Bull, R., and Filippou, D. (2010). Age-related differences in gaze following: does the age of the face matter? *J. Gerontol. B Psychol. Sci. Soc. Sci.* 65, 536–541. doi: 10.1093/geronb/gbq038

Slessor, G., Venturini, C., Bonny, E. J., Insch, P. M., Rokaszewicz, A., and Finnerty, A. N. (2016). Specificity of age-related differences in eye-gaze following: evidence from social and nonsocial stimuli. *J. Gerontol. B Psychol. Sci. Soc. Sci.* 71, 11–22. doi: 10.1093/geronb/gbu088

Süßenbach, F., and Schönbrodt, F. (2014). Not afraid to trust you: trustworthiness moderates gaze cueing but not in highly anxious participants. *J. Cogn. Psychol.* 26, 670–678. doi: 10.1080/20445911.2014.945457

Twele, A. M., Thierry, S. J., and Mondloch, C. (2022). Face masks have a limited influence on first impressions: evidence from three experiments. *Perception* 51, 417–434. doi: 10.1177/03010066221091729

Ueda, S., and Kitazaki, M. (2013). "Collision avoidance affected by walker's head direction in a virtual environment," in *International Conference on Human-Computer Interaction*. eds. S. Ueda and M. Kitazaki (Berlin, Heidelberg: Springer), 727–731.

Zorzi, M., Mapelli, D., Rusconi, E., and Umiltà, C. (2003). Automatic spatial coding of perceived gaze direction is revealed by the Simon effect. *Psychon. Bull. Rev.* 10, 423–429. doi: 10.3758/bf03196501

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Mapping the perception-space of facial expressions in the era of face masks

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With the advent of the severe acute respiratory syndrome-Corona Virus type 2 (SARS-CoV-2) pandemic, the theme of emotion recognition from facial expressions has become highly relevant due to the widespread use of face masks as one of the main devices imposed to counter the spread of the virus. Unsurprisingly, several studies published in the last 2 years have shown that accuracy in the recognition of basic emotions expressed by faces wearing masks is reduced. However, less is known about the impact that wearing face masks has on the ability to recognize emotions from subtle expressions. Furthermore, even less is known regarding the role of interindividual differences (such as alexithymic and autistic traits) in emotion processing. This study investigated the perception of all the six basic emotions (anger, disgust, fear, happiness, sadness, and surprise), both as a function of the face mask and as a function of the facial expressions' intensity (full vs. subtle) in terms of participants' uncertainty in their responses, misattribution errors, and perceived intensity. The experiment was conducted online on a large sample of participants (N = 129). Participants completed the 20-item Toronto Alexithymia Scale and the Autistic Spectrum Quotient and then performed an emotion-recognition task that involved face stimuli wearing a mask or not, and displaying full or subtle expressions. Each face stimulus was presented alongside the Geneva Emotion Wheel (GEW), and participants had to indicate what emotion they believed the other person was feeling and its intensity using the GEW. For each combination of our variables, we computed the indices of 'uncertainty' (i.e., the spread of responses around the correct emotion category), 'bias' (i.e., the systematic errors in recognition), and 'perceived intensity' (i.e., the distance from the center of the GEW). We found that face masks increase uncertainty for all facial expressions of emotion, except for fear when intense, and that disgust was systematically confused with anger (i.e., response bias). Furthermore, when faces were covered by the mask, all the emotions were perceived as less intense, and this was particularly evident for subtle expressions. Finally, we did not find any evidence of a relationship between these indices and alexithymic/autistic traits.

KEYWORDS

emotion recognition, alexithymia, autistic traits, COVID-19, face mask, facial expressions

Introduction

Communicating one's emotions and recognizing the emotions of others are crucial skills that allow an understanding of other people's affective states and intentions and help build/foster interpersonal relationships.

In this respect, humans, along with other primates, have developed a complex facial musculature that allows a rich variety of configurations, thereby enabling them to convey a multitude of possible emotions: muscles distributed in different areas of the face contribute to the production of different expressions. Conversely, an observer will use the visual information distributed over another person's face to recognize the emotion being expressed. Thus, it is clear that any circumstance that prevents a person from seeing another person's entire face will also reduce the degree of correct recognition of that person's expression and, therefore, of their emotion.

The advent of the COVID-19 pandemic and the introduction of face masks as a protective device to limit the spread of the infection has raised considerable interest in the context of studies on face processing, as masks made it impossible to view the entire lower half of the face. Several studies conducted after the beginning of the pandemic (and the use of face masks) have investigated potential patterns in the recognition of emotions by comparing conditions in which the faces were entirely visible with conditions in which the faces were covered by a mask (Carbon, 2020; Grundmann et al., 2020; Ruba and Pollak, 2020; Bani et al., 2021; Calbi et al., 2021; Carbon and Serrano, 2021; Fitousi et al., 2021; Gori et al., 2021; Grahlow et al., 2021; Kang et al., 2021; Lau, 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021; Sheldon et al., 2021; Ziccardi et al., 2021; Carbon et al., 2022; Grenville and Dwyer, 2022; Kastendieck et al., 2022; Kim et al., 2022; Langbehn et al., 2022; Maiorana et al., 2022; McCrackin et al., 2022; Parada-Fernández et al., 2022; Schneider et al., 2022; Tsantani et al., 2022). Previous studies had also investigated the ability to extract affective meaning from only partially visible faces, using different occlusion methods such as the following: presenting stimuli covered by hats, scarves, sunglasses, niqabs, or censoring black bars; degrading the quality of sections of the presented image; or progressively increasing the visual information available (Kret and de Gelder, 2012; Calvo and Fernández-Martín, 2013; Calvo et al., 2014; Wegrzyn et al., 2017; Kret and Fischer, 2018; Liedtke et al., 2018; Ruba and Pollak, 2020; Kret et al., 2021; Noyes et al., 2021; Kim et al., 2022). Overall, these studies found that the use of facial masks and other occlusion methods does interfere with the ability to accurately recognize facial expressions of emotion but not to the extent that it is reduced to chance level (Pavlova and Sokolov, 2022).

It should be noted that the degree of such interference has been found to vary according to the different emotions expressed. For example, it appears that the recognition of anger is not always affected by the occlusion caused by face masks. This would seem to indicate that access to the visual information conveyed by the upper portion of the face is sufficient for its correct recognition (Carbon and Serrano, 2021; Grenville and Dwyer, 2022; Schneider et al., 2022; Tsantani et al., 2022). Surprisingly, it has been observed how anger can be easier to identify when the lower part of the face is covered (Carbon and Serrano, 2021; Ziccardi et al., 2021; Grenville and Dwyer, 2022). The correct recognition of fear has also been found unnecessarily hindered by the use of face masks (Carbon, 2020; Ruba and Pollak, 2020; Bani et al., 2021; Carbon and Serrano, 2021; Pazhoohi et al., 2021; Carbon et al., 2022; Grenville and Dwyer, 2022). Recognition of the expressions of happiness, disgust, and sadness, on the other hand, tends to be particularly compromised when the face is covered. The misattribution errors that have been observed include confusing happiness with surprise (Ziccardi et al., 2021), anger with sadness (Kim et al., 2022; Schneider et al., 2022), disgust with anger (Carbon, 2020; Ziccardi et al., 2021; Carbon et al., 2022; Kim et al., 2022; Tsantani et al., 2022) and sadness (Carbon and Serrano, 2021; Ziccardi et al., 2021; Kim et al., 2022), and sadness with disgust (Carbon, 2020; Carbon et al., 2022; Kim et al., 2022), anger (Carbon et al., 2022; Kim et al., 2022; Schneider et al., 2022), and fear (Carbon, 2020; Carbon et al., 2022). Interestingly, it has also been found that the presence of face masks can result in observers mistaking happy expressions for neutral ones, erroneously considering the latter as expressions of sadness (Marini et al., 2021).

So far, almost all of the studies conducted have investigated the perception and recognition of intense facial expressions using static images as stimuli (Carbon, 2020; Grundmann et al., 2020; Ruba and Pollak, 2020; Calbi et al., 2021; Carbon and Serrano, 2021; Fitousi et al., 2021; Grahlow et al., 2021; Kang et al., 2021; Lau, 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021; Ziccardi et al., 2021; Carbon et al., 2022; Grenville and Dwyer, 2022; Kastendieck et al., 2022; Kim et al., 2022; Langbehn et al., 2022; Maiorana et al., 2022; McCrackin et al., 2022; Parada-Fernández et al., 2022; Schneider et al., 2022; Tsantani et al., 2022). The few exceptions to this have investigated the recognition of subtle (Bani et al., 2021; Gori et al., 2021; Sheldon et al., 2021) and ambiguous/blended (Wegrzyn et al., 2015) expressions using static pictures or short video clips as dynamic stimuli (Kastendieck et al., 2022; Langbehn et al., 2022). In most cases, the datasets used by the studies conducted so far have presented photos of actors reproducing specific emotions in an exaggerated and prototypical manner. The images selected to represent the target emotions that participants were asked to identify often portrayed expressions of an intense emotional activation, leaving little to no space for the representation of more subtle degrees of intensity. This choice of stimuli has led to an unnatural representation of reality since in everyday life, nature constantly presents us with subtly nuanced expressions of emotion. Addressing this issue is of great importance since recognizing subtly nuanced emotions may prove more arduous than recognizing the same emotions expressed in a more exaggerated manner, making it harder to avoid errors of judgment that were previously not observed. For this reason, in the present study, we decided to present stimuli showing both facial expressions portraying emotions felt very intensely and facial expressions representing emotions felt less strongly. To our knowledge, only three studies have specifically investigated the recognition of subtle expressions in adult faces covered by face masks. The first, conducted by Sheldon et al. (2021), studied the perception of different types of smiles (Duchenne and social), particularly demonstrating that the presence of face masks tends to reduce the perception of the social smile's pleasantness. The second study by Bani et al. (2021), on the other hand, investigated the ability of young medical and nursing students to recognize four basic emotions (fear, happiness, sadness, and anger) presented at different intensity levels, both with and without a face mask. The results of this study supported previous evidence by demonstrating an impaired recognition accuracy in the masked condition. Furthermore, with the exception of fear, different intensity levels in the masked condition produced a greater proportion/a higher number of emotion misattribution errors than were observed in the condition of complete facial visibility. The third study that was conducted by Gori et al. (2021) examined this topic from a developmental perspective, finding the use of face masks to have a negative impact on the ability of toddlers, children, and adults to infer emotions from masked facial configurations expressing happiness, fear, anger, and sadness or portraying a neutral expression. Moreover, the study found toddlers' performances to be the most affected by the presence of face masks when compared to those of both children and adults.

It has been observed that the presence of masks tends to impact the perception of an emotion's intensity. More specifically, when covered by masks, facial expressions tend to be perceived as more subdued. It has been observed that the same facial expression has been judged to convey an emotion less intensely when covered (Pazhoohi et al., 2021; Kastendieck et al., 2022; Tsantani et al., 2022). It has also been observed that some specific emotions seem to be more affected by this than others and that the perception of the intensity of happiness appears to be particularly compromised (Sheldon et al., 2021; Langbehn et al., 2022; Ramachandra and Longacre, 2022). Another interesting aspect is that not only does the intensity of target emotions displayed behind masks appear to be reduced, but also when asked to indicate whether other distractor emotions are perceived as present in the image, participants tend to indicate these as more present in faces covered by masks than in fully visible faces (e.g., Tsantani et al., 2022).

The lack of in-depth knowledge regarding how the presence of face masks affects the perception of emotions' intensity may be due to the fact that the majority of studies conducted so far have employed tasks requiring participants to assess a person's emotional state from a limited list of given emotions (Kret and Fischer, 2018; Liedtke et al., 2018; Carbon, 2020; Grundmann et al., 2020; Ruba and Pollak, 2020; Bani et al., 2021; Calbi et al., 2021; Carbon and Serrano, 2021; Gori et al., 2021; Grahlow et al., 2021; Kang et al., 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021; Ziccardi et al., 2021; Carbon et al., 2022; Grenville and Dwyer, 2022; Kim et al., 2022; Maiorana et al., 2022; McCrackin et al., 2022; Parada-Fernández et al., 2022; Schneider et al., 2022). Although such methods allow one to observe whether participants confuse the facial expressions of one emotion with another unintended one, they do not provide any information regarding the perception of the intensity of the emotion identified. In this study, we therefore decided to ask participants to provide us with this information by using the Geneva Emotion Wheel (GEW; Scherer, 2005; Scherer et al., 2013) to indicate their perception of the emotional intensity expressed by the target stimuli.

To date, most published studies have chosen to select stimuli representing only a limited variety of emotions (a range of three to four emotions) (Kret and Fischer, 2018; Liedtke et al., 2018; Ruba and Pollak, 2020; Bani et al., 2021; Calbi et al., 2021; Fitousi et al., 2021; Lau, 2021; Marini et al., 2021; Kastendieck et al., 2022; Maiorana et al., 2022; Parada-Fernández et al., 2022; Schneider et al., 2022). In the present study, we therefore decided to assess recognition of all the six basic emotions. Interestingly, the valence of the emotions selected in these previous studies has not always been evenly represented. For example, in some studies, happiness has been the only emotion with positive valence (Kret and Fischer, 2018; Liedtke et al., 2018; Bani et al., 2021; Marini et al., 2021; Maiorana et al., 2022; Schneider et al., 2022). In experiments presenting participants with a forced-choice task, this has occasionally created a real risk of registering a ceiling effect, as observed in Kastendieck et al. (2022). Moreover, the number of studies using stimuli representing a range of emotions presented with varying degrees of intensity is, at present, very restricted (Bani et al., 2021; Gori et al., 2021; Sheldon et al., 2021). As a result, the recognition of certain emotions (such as disgust or surprise) presented in subtle expressions and partly hidden by masks has seldom been studied.

Finally, very few studies have investigated the associations between the presence of clinical traits and difficulties in recognizing facial expressions of emotions covered by masks (Calbi et al., 2021; Pazhoohi et al., 2021; Ziccardi et al., 2021; Maiorana et al., 2022; McCrackin et al., 2022; Ramachandra and Longacre, 2022). Many studies have, however, investigated normal-typical subjects' behavior both in relation to traits associated with social affiliation (Calbi et al., 2021), empathy (Liedtke et al., 2018; Calbi et al., 2021; Trainin and Yeshurun, 2021; Carbon et al., 2022; McCrackin et al., 2022; Ramachandra and Longacre, 2022) and in relation to personal impressions regarding the COVID-19 pandemic (Grundmann et al., 2020; Calbi et al., 2021; Trainin and Yeshurun, 2021; Carbon et al., 2022; Tsantani et al., 2022). Autism and alexithymia traits are hypothesized to be among the clinical traits thought to be particularly affected by the presence of facial masks. Not all of the studies that have submitted questionnaires investigating the presence of alexithymic traits (Calbi et al., 2021; Maiorana et al., 2022) have used the gathered data to analyze the relationship between the presence of such traits and participants' performance in emotion-recognition tasks, showing only the upper part of the face (see Calbi et al., 2021). The limited sample sizes analyzed in studies examining the presence of autistic traits in participants performing facial-expressions recognition tasks (Pazhoohi et al., 2021; McCrackin et al., 2022; Ramachandra and Longacre, 2022), have often prevented them from reaching clear-cut conclusions. Furthermore, these studies have frequently presented participants with stimuli showing only cut-away sections of the human face expressing the target emotion (for example, the eyes) rather than specifically addressing the issue of facial-expression recognition in the presence of face masks.

The present study aimed to clarify how the perception of all the six basic emotions (anger, disgust, fear, happiness, sadness, and surprise) varies both according to whether the face observed has been covered by a face mask and according to the intensity of the facial expression represented (full—100% vs. subtle—40%). We also explored whether individuals' autistic and alexithymic traits may have an impact on facial-expression recognition.

We used the GEW (Scherer, 2005; Scherer et al., 2013) to collect responses from participants. The GEW is an instrument designed to combine both a discrete and a dimensional approach in the self-report assessment of emotion (see the upper panel of **Figure 1**). We chose this tool because it allowed us to evaluate the participants' performance for all six basic emotions by concurrently reducing the probability of ceiling effects. It also allowed us to measure three different indices based on participants' single responses (i.e., single clicks on the wheel): (1) uncertainty in their responses (the spread around the angle of the correct emotion category segment), i.e., the tendency to confuse (not necessarily in a systematically direction) one emotion with others; (2) response bias (the mean angle of deviation from the angle of the correct emotion category segment), i.e., the systematic tendency to confuse one emotion with another emotion/other emotions by systematically choosing emotion categories positioned clockwise or anticlockwise in the GEW; and (3) perceived intensity (the mean distance from the center of the GEW).

Since the presence of face masks reduces the available information helping a person to decide which emotion is being expressed by a face, we expected—on the basis that information can be conceived as a reduction of uncertainty—to find that the manipulation involving the presence or absence of a mask would have an impact on the uncertainty index for *all facial expressions*. That is to say, we hypothesized an increased uncertainty in the participants' responses relating to facial expressions covered by a mask, compared to those relating to uncovered facial expressions. If this is the case, this effect would offer an index for quantifying more precisely the impact of face masks on participants' confidence in their judgment, which is reduced as a function of face masks (Carbon, 2020). We further expected a greater increase in uncertainty for subtle facial expressions since they provide even less overall available information when covered by face masks. Nevertheless, we envisaged that facial expressions characterized by highly distinctive modifications in the upper portion of the face could be immune to this reduction of information, especially when intense.

Applying Action Units (AUs; Ekman and Friesen, 1978[1]) as diagnostic information for the correct recognition of emotional expressions, the basic emotions conveyed primarily by the lower portion of the face are *disgust* (characterized by wrinkling of the nose and lifting of the upper lip) and *happiness* (mainly characterized by the raising of the corners of the mouth). With regard to disgust, the only additional secondary AU possibly available when the face is covered is AU7 (tension of the inferior eyelid). It should be noted that the only expression

1 "The Facial Action Coding System (FACS; Ekman and Friesen, 1978) is a comprehensive, anatomically based system for describing all visually discernible facial movement. It breaks down facial expressions into individual components of muscle movement, called Action Units (AUs)." (From https://www.paulekman.com/facial-action-coding-system/).

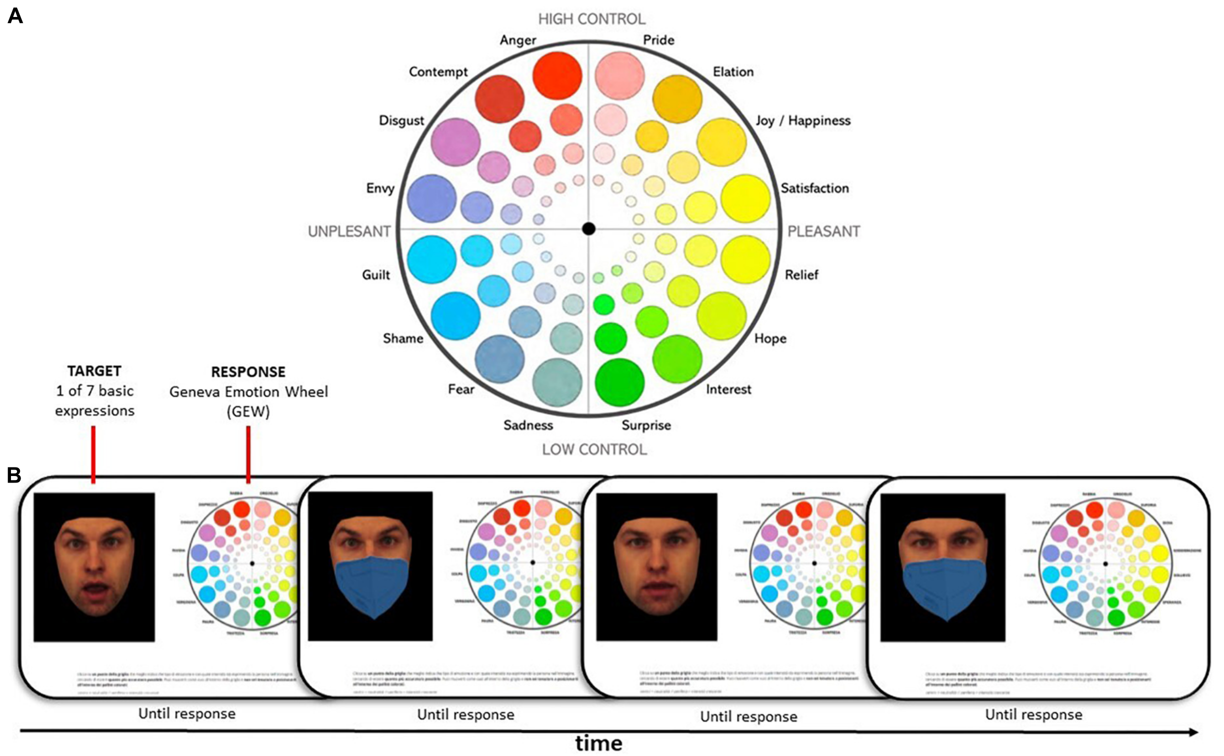

FIGURE 1
Description of the experimental paradigm. **(A)** English version of the GEW 1.0. During the experiment, the labels were presented in Italian. **(B)** Trial example. Each trial consisted of a screen with the target face with or without the facial mask. The facial expression intensity could be full or subtle (except for neutral faces). Next to the face, the GEW was used to collect the response. There was no time limit, and the next trial start was self-paced. Images reproduced from KDEF (Lundqvist et al., 1998) with permission. Identity AM02 from the KDEF image set is depicted.

distinctively characterized by AU7 is anger. Therefore, it may be hypothesized that, when observing a face covered by a mask, the expression of disgust may be confused with anger. On this basis, we expected to observe a response bias toward anger in cases where expressions of disgust were subject to face-mask manipulation. With regard to happiness, there are many additional AUs that can be activated, so we did not make any specific hypotheses about whether the presence of face masks could impact the response bias.

We expected to replicate previous results regarding the degree of intensity perceived as a function of the mask (e.g., Pazhoohi et al., 2021; Kastendieck et al., 2022; Tsantani et al., 2022) and, therefore, to observe a reduction in the perceived intensity of the expressions covered by face masks when compared to uncovered expressions. Furthermore, we expected to find this effect to be particularly evident for subtle expressions, considering they could be more easily misinterpreted as neutral expressions.

Finally, we expected to find that all the hypothesized effects described above would also correlate with alexithymic and autistic traits assessed by means of the 20-item Toronto Alexithymia Scale (20-item TAS; Bagby et al., 1994) and the Autism Quotient (AQ; Baron-Cohen et al., 2001). We expected to observe a relationship between these traits and the three indices described above.

Materials and methods

Participants

We recruited a total of 139 volunteers to participate in this study. The data obtained from 10 participants were not included in our analyses because the level of accuracy of the responses registered in the catch trials was not deemed sufficient, which is <75% accuracy. We arbitrarily decided that performance above 75% accuracy on catch trials was sufficient to ensure that the participants had focused on the main task. Thus, our final sample size consisted of 129 participants, of whom 116 were women (M_{age} = 23.3, SD = 2.99) and 13 were men (M_{age} = 26.4, SD = 6.45).

All participants were Italian native speakers of Italian nationality to avoid registering possible differences linked to the culture of origin of those participating. To ensure a correct and homologous vision of the stimuli, participants were explicitly requested to perform the test from their personal computers only, after having duly calibrated their screen following specific instructions; this allowed everyone to view both the images of the target stimuli and the GEW in the same dimensions (8 cm width for the target stimuli and 300 × 300 pixels for the GEW). The study was created to be administered online, and volunteers were mainly recruited *via* announcements posted on social networks. The majority of the sample comprised students from the University of Padua. All volunteers provided informed consent before participating in the study.

Materials

Questionnaires

Participants were asked to complete a questionnaire providing their demographic data and contact information. They also completed the TAS-20 questionnaire to investigate the presence of alexithymic traits (Bagby et al., 1994) and the AQ questionnaire to investigate the presence of autistic traits (Baron-Cohen et al., 2001).

Stimuli

A total of 260 experimental stimuli and 14 catch trials were administered during the test phase, which was preceded by a familiarization phase involving 10 stimuli and 1 catch trial. Seventy face stimuli were selected from the Karolinska Directed Emotional Faces database (KDEF[2]; Lundqvist et al., 1998), for a total of 10 Caucasian identities (5 female and 5 male face stimuli; AF05, AF06, AF07, AF08, AF09, AM01, AM01, AM02, AM03, AM04, AM05, and AM06) portraying the 6 basic emotions (anger, disgust, fear, happiness, sadness, and surprise) and the neutral expression.

The images were modified with a Face Morpher script[3] by morphing each of the six emotional expressions with the neutral expression to obtain a realistic facial conformation with an intensity of the expressed emotion equal to 40%. This allowed us to obtain full and subtle expressions of each of the six basic emotions. Given that the background of each image was removed and replaced by a black backdrop, each stimulus consisted solely of a face portraying the target emotion. Each stimulus was then duplicated and an N95 mask was affixed to each copy, using the MaskTheFace script[4]. As a result, each facial expression was represented by an unmasked and a masked face expressing both a full and a subtle manifestation of intensity. Each catch trial consisted of an image of the same size as those containing faces, with a sentence written in white color (in Italian) on a black background asking the participant to click on a specific position of the Geneva Emotion Wheel. The request was different for each of the 14 catch trials, and they were randomly presented during the experimental phase (7 per block). Each facial stimulus was presented to participants only once, and each participant saw all of the ten identities with block randomization across subjects. Trails were randomized within each block but they were not randomized between blocks. To summarize, we administered 240 emotional faces (60 masked/100% intensity, 60 masked/40% intensity, 60 unmasked/100% intensity, and 60 unmasked/40% intensity), plus 20 neutral faces (10 masked and 10 unmasked), plus 14 catch trials, for a total of 274 trials.

Geneva emotion wheel

We used the Geneva Emotion Wheel (GEW 1.0; Tran, 2004; Vaughan, 2011) to gather the participants' responses. The terms used to refer to the emotions included in the GEW were translated into Italian by bilingual English/Italian speakers. The GEW 1.0 presents 16 terms indicating different emotions arranged around the wheel's circumference. Each emotion is represented by a series of 4 differently sized circles proceeding outward from the center of the circle, with their size corresponding to the increasing intensity of the emotion perceived. The center of the wheel thus represents a point of neutrality. The emotions are distributed according to the degree of control/power (low at the bottom of the GEW and high at the top) and the valence (with the more negative emotions arranged on the left and the more positive emotions arranged on the right). The GEW was originally designed to allow participants to indicate their experienced emotions as precisely as possible, but it has also been used on several occasions to indicate perceived emotions in others (e.g., Siegert et al., 2011; Zheng and Xia, 2012; Coyne et al., 2020). This tool seeks to represent emotions both discretely and continuously; emotions that partially share the same characteristics of control and valence are placed in proximity but constitute distinct radii; emotions that possess opposite characteristics are placed diametrically opposite to each other. We decided to use the GEW and, specifically, version 1.0 (Tran, 2004; Vaughan, 2011), which includes 16 emotions (plus the neutral condition) and 4 degrees of intensity, for the following reasons: (i) it is easy for participants to use; (ii) its use avoids ceiling effects because participants have to choose the correct emotion from among a series of distractors; and (iii) because the latest 3.0 version does not include the basic emotion of "surprise."

Procedure

We used the Gorilla Experiment Builder[5] to create and host our experiment (Anwyl-Irvine et al., 2020). The experiment lasted about 40 min and was carried out using a computer online. After giving their consent and completing the TAS-20

2 https://www.kdef.se/
3 https://github.com/alyssaq/face_morpher
4 https://github.com/aqeelanwar/MaskTheFace
5 http://www.gorilla.sc/

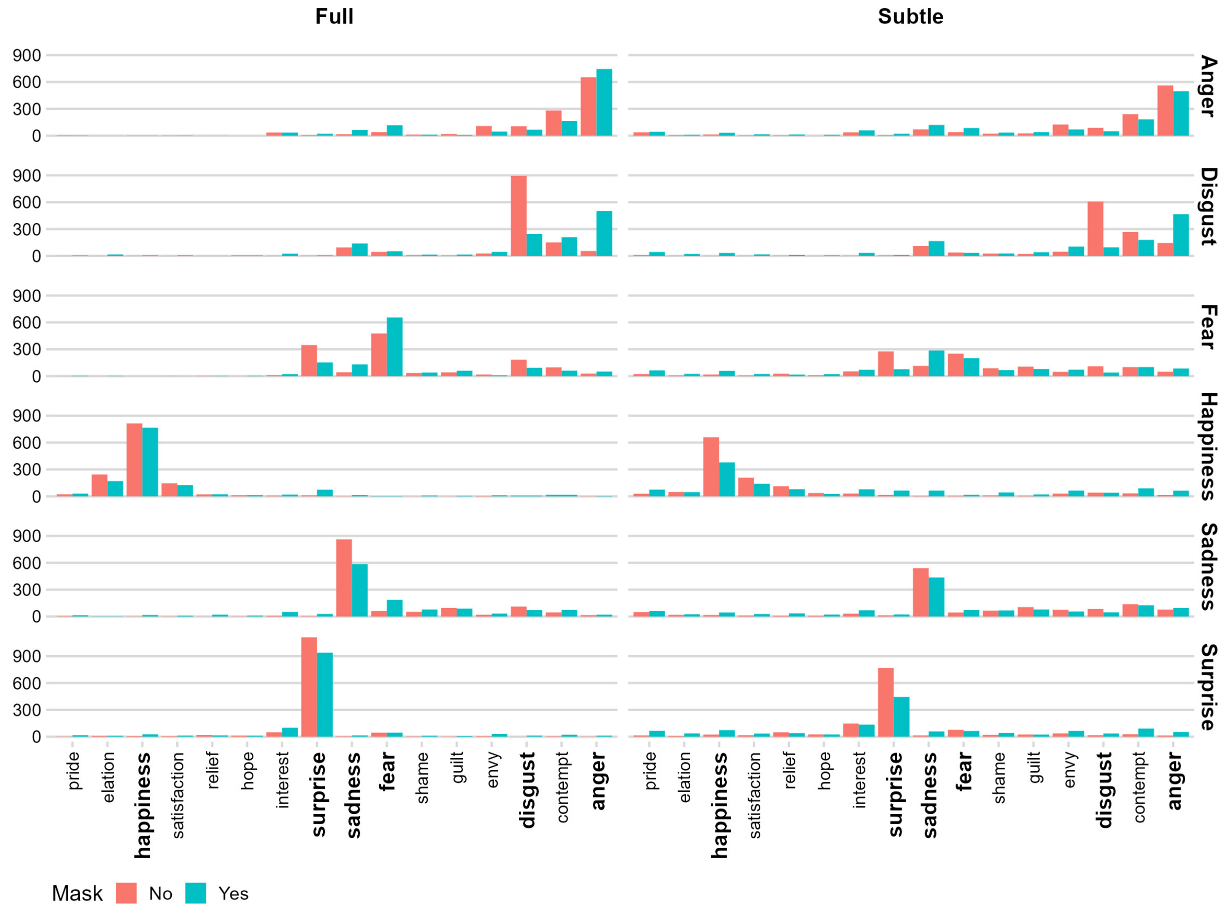

FIGURE 2
GEW responses as a function of displayed Emotion, Mask, and Facial Expression Intensity. Each participant's response was classified according to the position on the GEW to assign a label. The order of the *X*-axis corresponds to the clockwise order of the GEW. The *Y*-axis represents relative frequencies in each condition.

and AQ questionnaires, participants began the experimental session. They received the experimental instructions, were familiarized with the GEW, and performed a series of test trials. More specifically, participants were told that they could click anywhere on the wheel, including outside the circles if they felt it was appropriate. The face stimulus, the GEW, and a reminder of the instructions were simultaneously presented during each trial (see **Figure 1**; identity AM02 from the KDEF is depicted in **Figure 1**). The session was divided into two randomized blocks each comprising 137 trials and lasting approximately 15 min. The two blocks were separated by a pause, the length of which was decided by each participant. Full, subtle, and neutral emotions were randomly presented in each block. Each emotion was represented by different models and each model represented all the emotions that were presented as stimuli. The stimuli were presented without a time limit and the subsequent trial started immediately after the participant had given a response by clicking on the GEW. Only one response was accepted for each trial. Catch trials were distributed throughout the experiment to ensure that participants were vigilant while providing their answers.

Data analysis

To assess participants' perception of the facial expressions they were presented with, we transformed their responses into polar coordinates. The Euclidean distance from the GEW center (measured in pixels) indicates the *perceived intensity* of the emotion evaluated. Facial expressions perceived as more intense are represented by a greater distance. The *angle,* measured in degrees, corresponds to the response orientation around the GEW. We created a measure of participants' performance by computing the difference between the *response* angle (in radians) and the angle of the presented emotion (i.e., the *correct* angle). The correct angle was computed by dividing the GEW into equal parts and then centering each emotion. For better interpretability, we transformed the angles into degrees. In this way, we centered participants' responses on the displayed emotion with errors that ranged between −180° and 180°. Values around 0 mean correct responses while negative and positive values represent, respectively, an anticlockwise and clockwise shift of responses on the wheel.

This measure allowed us to extract two important indices. The circular mean of responses representing the average direction on the circle, relating to the displayed emotion, constitutes the *bias*. When the *bias* is different from zero, there is evidence of a systematic response shift to another location on the GEW.

The circular variability constitutes the *uncertainty* and, independently of the bias, it provides information about the amount of spread in participants' responses. For example, an emotion could be systematically confused with other emotions (i.e., *bias* different from 0), but this misattribution may be characterized by a low level of *uncertainty,* or, in another scenario, there could be no systematic *bias* toward a specific direction but a high-response *uncertainty* (i.e., greater circular variance).

Given the shape of the GEW, to analyze our data, standard statistical models were not appropriate (Cremers and Klugkist, 2018). Therefore, we decided to use a generalized linear mixed model, using the Von Mises distribution as the likelihood function to model both the *bias* and the *uncertainty*. The Von Mises is the circular version of the Gaussian distribution where parameters (μ and k) are directly associated with our *bias* and *uncertainty* indices. The parameter μ (the circular mean) represents the *bias* and the k parameter (the Von Mises *concentration*) represents the *uncertainty*. To facilitate interpretation, we transformed k into circular variance (Evans et al., 2011, 191–192). With this transformation, k values are bounded between 0 (i.e., all values are concentrated on a single point, minimum *uncertainty*) and 1 (i.e., values are uniform around the circle, maximum *uncertainty*). Given the relevance and the independence of *bias* and *uncertainty,* we

TABLE 1 Posterior distribution summaries for the *bias* and *uncertainty* Mask effect as a function of the displayed Emotion.

Emotion	Parameter	Mask$_{yes}$	Mask$_{no}$	Contrast
Surprise	Bias	−0.576 [−3.997, 2.751]	−0.846 [−2.216, 0.525]	0.28 [−3.342, 3.829]
Sadness		24.284 [20.466, 28]*	29.292 [26.641, 32.021]*	−4.972 [−9.738, −0.548]*
Happiness		2.553 [−0.427, 5.581]	2.834 [1.496, 4.167]*	−0.276 [−3.609, 2.855]
Fear		6.28 [2.779, 9.595]*	5.463 [2.789, 8.159]*	0.835 [−3.548, 5.121]
Disgust		17.735 [15.205, 20.43]*	−0.657 [−2.162, 0.859]	18.392 [15.403, 21.321]*
Anger		−22.361 [−25.222, −19.563] *	−20.244 [−22.062, −18.403] *	−2.125 [−5.526, 1.132]
Surprise	Uncertainty	0.441 [0.419, 0.464]*	0.166 [0.152, 0.179]*	2.818 [2.608, 3.033]*
Sadness		0.533 [0.507, 0.559]*	0.415 [0.392, 0.439]*	1.324 [1.237, 1.415]*
Happiness		0.418 [0.395, 0.44]*	0.156 [0.144, 0.169]*	2.842 [2.635, 3.068]*
Fear		0.481 [0.457, 0.507]*	0.467 [0.439, 0.493]*	0.997 [0.935, 1.061]
Disgust		0.449 [0.423, 0.475]*	0.203 [0.187, 0.219]*	2.229 [2.064, 2.401]*
Anger		0.474 [0.447, 0.5]*	0.278 [0.258, 0.298]*	1.714 [1.592, 1.836]*

Distributions are summarized using the median and 95% HPDI. Asterisks represent contrasts where the null value (i.e., 0 for deltas or 1 for ratios) is not contained in the 95% HPDI.

TABLE 2 Posterior distribution summaries for the *bias* and *uncertainty* Facial Expression Intensity effect as a function of the displayed Emotion.

Emotion	Parameter	Δ $Mask_{\mathrm{full}}$	Δ $Mask_{\mathrm{subtle}}$	Contrast
Surprise	Bias	0.031 [−2.378, 2.36]	0.513 [−6.448, 7.235]	−0.461 [−8.005, 6.513]
Sadness		1.572 [−2.076, 5.417]	−11.512 [−20.061, −3.229]*	13.09 [3.846, 22.37]*
Happiness		3.473 [1.155, 5.784]*	−4.026 [−10.139, 1.936]	7.496 [1.117, 14.079]*
Fear		−0.981 [−5.034, 3.2]	2.617 [−4.97, 10.195]	−3.595 [−12.151, 5.129]
Disgust		19.08 [15.563, 22.79]*	17.692 [12.967, 22.375]*	1.393 [−4.409, 7.449]
Anger		−0.032 [−3.703, 3.827]	−4.212 [−9.673, 1.349]	4.171 [−2.498, 10.848]
Surprise	Uncertainty	3.073 [2.74, 3.433]*	2.559 [2.303, 2.81]*	1.2 [1.026, 1.387]*
Sadness		1.425 [1.281, 1.583]*	1.221 [1.13, 1.317]*	1.166 [1.022, 1.325]*
Happiness		3.128 [2.784, 3.491]*	2.552 [2.307, 2.811]*	1.226 [1.047, 1.416]*
Fear		0.718 [0.647, 0.795]*	1.274 [1.173, 1.377]*	0.563 [0.492, 0.639]*
Disgust		2.326 [2.083, 2.581]*	2.128 [1.917, 2.347]*	1.094 [0.937, 1.254]
Anger		1.732 [1.554, 1.919]*	1.693 [1.538, 1.856]*	1.023 [0.884, 1.173]

Distributions are summarized using the median and 95% HPDI. Asterisk Represents contrasts where the null value (i.e., 0 for deltas or 1 for ratios) is not contained in the 95% HPDI.

decided to analyze both aspects in the same model. Using the so-called location-scale modeling (Rigby and Stasinopoulos, 2005; Bürkner, 2018), both μ (*bias*) and *k* (*uncertainty*) can be predicted within the same model. To model the *perceived intensity*, we used a standard general linear mixed-effects model. In dealing with the multilevel data structure, we added the participants' random effect in each model.

As predictors, we used *Mask* (faces with and without the facial mask), *Facial Expression Intensity* (full and subtle), and the displayed *Emotion* (anger, happiness, fear, surprise, disgust, and sadness).

As an exploratory analysis, we also analyzed the impact of alexithymia and autistic traits using the TAS and the AQ questionnaire. In this case, we fitted a model with the interaction between Mask and TAS/AQ for *bias*, *uncertainty,* and *perceived intensity*. Given that the Mask effect could be different according to the Facial Expression Intensity, we fitted the same model considering only the subtle facial expressions.

We calculated all models under Bayesian framework. Bayesian statistics combine previous knowledge (i.e., *priors*) with empirical data (i.e., the *likelihood*) to compute the *posterior* probability. We decided to use a Bayesian approach for several reasons. Firstly, compared to the frequentist approach, each parameter in a Bayesian regression model is represented by a probability distribution of plausible values after combining data with prior knowledge, instead of a single estimated value (Kruschke and Liddell, 2018). Secondly, the Bayesian framework allows more modeling flexibility and reliability for complex models (Bolker et al., 2009). To our knowledge, the location-scale Von Mises regression can be easily implemented only within a Bayesian framework.

For the model fitting, we used the *brms* package (Bürkner, 2017, 2018) based on the STAN probabilistic programming language (Stan Development Team, 2022) and R (R Core Team, 2022). We decided to use weakly informative priors for regression parameters (Gelman, 2006; Gelman et al., 2017). These priors allow more modeling efficiency by excluding very implausible or impossible values. In this way, posterior distributions are mainly influenced by the data (i.e., *likelihood*). All models converged according to the Gelman and Rubin (1992) $\hat{R}$ value. Details of the Models, the priors' specifications, and the diagnostics are available in the **Supplementary material** and the online OSF repository[6].

For each response variable, we used the following analytical approach. We tested the Mask effect (Δ Mask = $\text{Mask}_{yes} - \text{Mask}_{no}$) for each displayed emotion. This allowed us to directly assess the impact of the facial mask on facial-expression perception in terms of *bias* and *perceived intensity*. For the *uncertainty,* the Mask effect is computed using the ratio between conditions (Ratio Mask = $\text{Mask}_{yes}/\text{Mask}_{no}$), as commonly used for variance-like measures (Nakagawa et al., 2015).

Next, we tested whether the Mask effect differs when considering *subtle* or *full* facial expressions. First, we compared the model with and without the three-way interaction among Mask, Emotion, and Facial-expression Intensity using the Pareto-Smoothed Importance Sampling Leave-One-Out cross-validation criterion (PSIS-LOO). The PSIS-LOO is a more robust variant of the WAIC index (i.e., the Bayesian alternative to the Akaike Information Criterion) that can be used for model comparisons (Vehtari et al., 2017). In this way, we can assign a probability value to both models and find the most plausible. Then, we calculated the Intensity effect as the difference between Mask deltas for *subtle* and *full* facial expressions (Δ Intensity = $\Delta\ \text{Mask}_{full} - \Delta\ \text{Mask}_{subtle}$) in relation to the *bias* and the *perceived intensity*. For the *uncertainty,* we calculated the ratio between Mask ratios (Ratio Intensity = Ratio Mask_{full}/Ratio Mask_{subtle}).

We summarized each model parameter or posteriors contrast using the median and the 95% Highest Posterior Density Interval (HPDI). The 95% HPDI is the interval of the posterior distribution that contains 95% of the most plausible values (Kruschke and Liddell, 2018). We consider a result as statistically significant if the null value, e.g., 0 is not contained within the 95% HPDI. For the *perceived intensity* and *bias,* each relevant contrast (i.e., difference) is bidirectionally tested against 0, whereas for the *uncertainty,* we tested the contrasts (i.e., ratio) against 1. If possible, we reported the Bayes Factor calculated using the Savage-Dickey density ratio (Wagenmakers et al., 2010) to support evidence for the null effect.

Results

Participants' responses as a function of Mask, Facial-Expression Intensity, and Emotion, expressed through the GEW location, are depicted in **Figure 2**.

Bias

The first model predicts the *bias* with Mask, Emotion, and Facial-Expression Intensity as predictors. Posterior distribution summaries for the Mask effect and the interaction between Mask and Facial-Expression Intensity are presented in **Tables 1**, **2**, respectively.

Mask effect

Figure 3 summarizes each posterior distribution and the Mask effect. Facial expressions of sadness, disgust, fear, anger, and happiness have a *bias* different from 0. For disgust, the *bias* is only present when the face is presented with a facial mask.

6 https://osf.io/e2kcw/

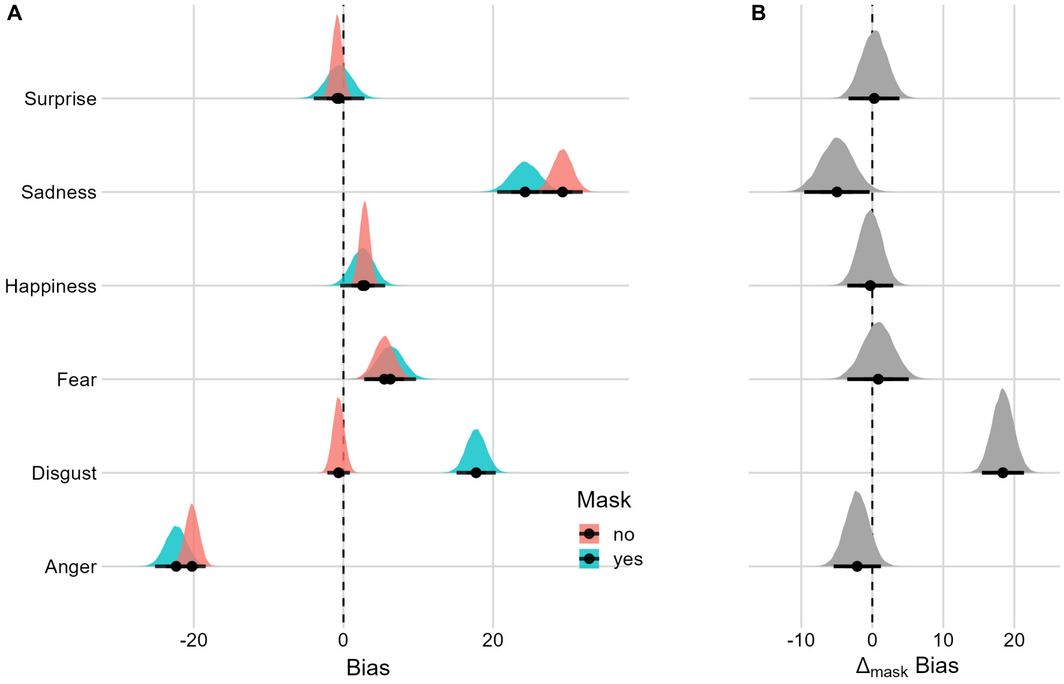

FIGURE 3
Posterior distributions and 95% HPDIs of the *bias* Mask effect **(A)** *Bias* posterior distributions as a function of the Mask condition. **(B)** Posterior distributions of the Mask Δ contrast ($\text{Mask}_{\text{yes}} - \text{Mask}_{\text{no}}$).

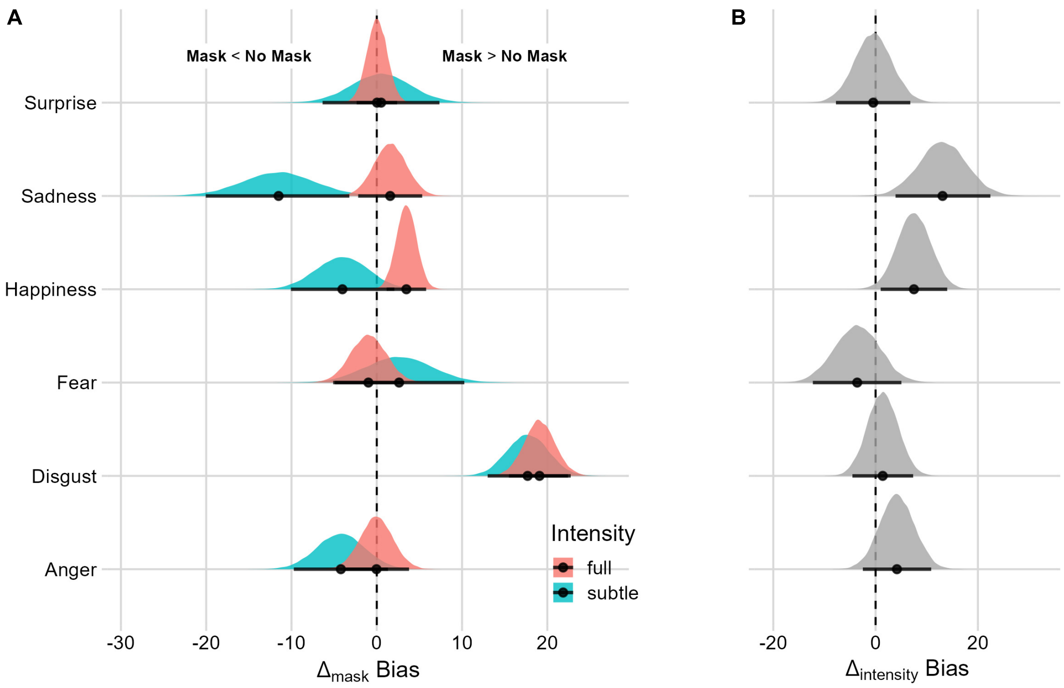

FIGURE 4
Posterior distributions and 95% HPDIs of the bias Facial Expression Intensity Effect. **(A)** Posterior distributions of Mask Δ as a function of the Facial Expression Intensity condition. **(B)** Posterior distribution of the Facial Expression Intensity Δ contrast (Mask Δ_{full} − Mask Δ_{subtle}).

In terms of the Mask effect, facial expressions of sadness and disgust are associated with different *bias* values. With disgusted faces, in particular, the presence of the mask clearly increases the response *bias*. Despite being smaller, the Mask effect for sad faces is reversed where the presence of the mask reduces the response *bias*. We did not find a Mask effect for a surprise.

Mask and facial-expression intensity interaction

We assessed the Mask effect for the subtle and full *Facial-Expression Intensity* (see **Figure 4** and **Table 2**). The model with the three-way interaction (mask, emotion and Facial-Expression Intensity, LOO = −40,133.1, SE = 196.2, p_{model} = 0.723) is 2.6 times more likely than the model without the three-way interaction (LOO = −40,150.5, SE = 195.6, p_{model} = 0.277). The Mask effect differs in relation to subtle and full facial expressions only for facial expressions of sadness and happiness. More specifically, for facial expressions of happiness at full intensity, the bias is greater with the mask. For subtle facial expressions of sadness, the effect is reversed, with greater bias in the condition without the Mask. We did not find a difference in the Mask effect between subtle and full facial expressions when considering faces with a facial expression of surprise.

Uncertainty

The first model also predicts the *uncertainty* with Mask, Emotion, and Facial-Expression Intensity as predictors. Posterior distribution summaries for the Mask effect and the interaction between Mask and Facial-Expression Intensity are presented respectively in **Tables 1**, **2**.

Mask effect

For *uncertainty* (**Figure 5** and **Table 1**) we followed the same approach as above. Overall, the *uncertainty* is lower for the condition without the mask. There is evidence of the Mask effect for each emotion except fear.

Mask and facial-expression intensity interaction

Assessing the Mask effect for subtle and full facial expressions (**Figure 6** and **Table 2**), there is evidence of a difference in *uncertainty* ratios for facial expressions of surprise, sadness, fear, and happiness. For fearful faces, the Mask effect is reversed between subtle and full facial expressions. When the intensity is subtle, there is more uncertainty in the masked condition, whereas, for full-intensity, expression generates more uncertainty without the mask. For surprise, sadness, and happiness, the Mask effect is present for both full and subtle facial expressions. Despite a smaller effect, when considering the difference between full and subtle intensity, the Mask effect is lower with subtle facial expressions.

Perceived intensity

The second model predicts *perceived intensity* with Mask, Emotion, and Facial-expression Intensity as predictors. Posterior distribution summaries for the Mask effect and the interaction between Mask and Facial-Expression Intensity are presented respectively in **Tables 3**, **4**.

Mask effect

The *perceived intensity* is generally lower when the mask is present. **Figure 7** and **Table 3** report the *perceived intensity* in each condition and the Mask effect. There is evidence of the Mask effect for each displayed emotion.

Mask and facial-expression intensity interaction

To assess the effect of the facial-expression intensity, we first compared the model with and without the three-way interaction (mask, emotion, and facial-expression intensity). The model with the three-way interaction (LOO = −169,115.6, SE = 127.3, p_{model} = 0.753) is 3 times more likely than the model without the three-way interaction (LOO = −169,121.6, SE = 127.4, p_{model} = 0.247). With the exception of sadness, the Mask effect is greater for subtle facial expressions for each displayed emotion (**Figure 8** and **Table 4**).

Toronto Alexithymia Scale and Autism Quotient

The average scores of TAS and AQ in our sample were respectively 14.9 (SD = 6.62, IQR = 8) and 52.1 (SD = 8.53, IQR = 12).

We centered TAS and AQ scores and set sum contrasts on the Mask predictor for better interpretability of model parameters (Schad et al., 2020). The TAS has no effect on the response *bias* (β = −0.0002, SE = 0.0004, 95% HPDI = [−0.001, 0.001], $log\mathrm{BF}_{01}$ = 6.93). Furthermore, there is no interaction between TAS and the presence of the mask (β = −0.0003, SE = 0.0007, 95% HPDI = [−0.0017, 0.001], $log\mathrm{BF}_{01}$ = 6.47).

There is also no evidence of a TAS effect on the *uncertainty* parameter either for the TAS main effect (β = 0.001, SE = 0.002, 95% HPDI = [−0.003, 0.006], $log\mathrm{BF}_{01}$ = 5.21) or for the interaction between TAS and Mask (β = 0.001, SE = 0.002, 95% HPDI = [−0.003, 0.004], $log\mathrm{BF}_{01}$ = 5.53).

When considering only the subtle facial expressions, there is no relationship between *bias* and TAS scores (β = 0.001, SE = 0.001, 95% HPDI = [−0.001, 0.002], $log\mathrm{BF}_{01}$ = 6.753) and no interaction between TAS and the presence of the mask (β = −0.001, SE = 0.001, 95% HPDI = [−0.004, 0.001], $log\mathrm{BF}_{01}$ = 6.038). For the *uncertainty,* we found no main effect of TAS (β = 0.002, SE = 0.003, 95% HPDI = [−0.004, 0.008], $log\mathrm{BF}_{01}$ = 5.592), and no interaction between TAS

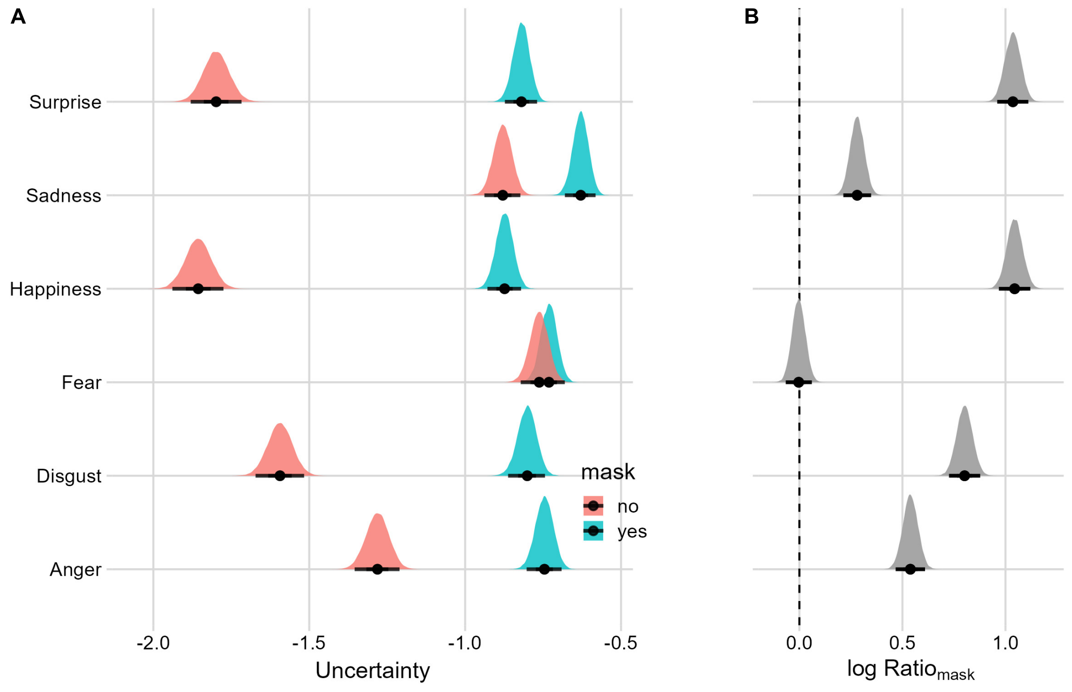

FIGURE 5
Posterior distributions and 95% HPDIs of the uncertainty Mask effect **(A)** *uncertainty* posterior distributions as a function of the Mask condition. **(B)** Posterior distribution of the Mask Ratio ($Mask_{yes}/Mask_{no}$). Values are plotted on the logarithm scale for better visualization (the null value is 0).

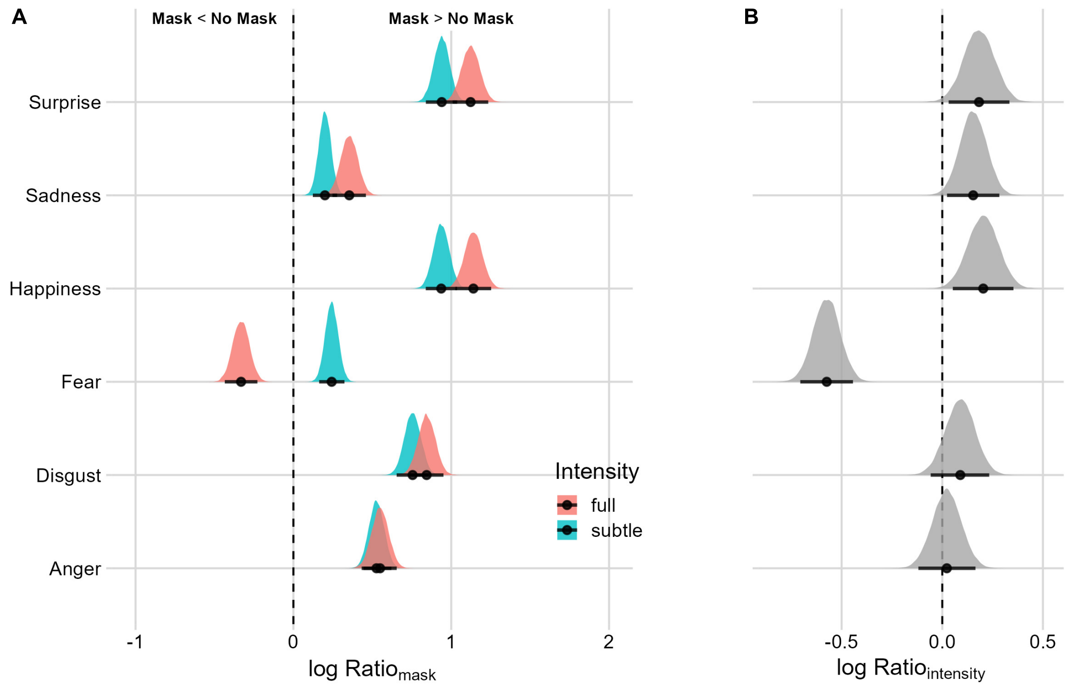

FIGURE 6
Posterior distributions and 95% HPDIs of the uncertainty Facial Expression Intensity Effect **(A)** uncertainty posterior distributions as a function of the Facial Expression Intensity condition. **(B)** Posterior distribution of the Facial Expression Intensity Ratios (Mask $Ratio_{full}$/Mask $Ratio_{subtle}$). Values are plotted on the logarithm scale for better visualization (the null value is 0).

TABLE 3 Posterior distribution summaries for the *perceived intensity* Mask effect as a function of the displayed Emotion.

Emotion	$Mask_{yes}$	$Mask_{no}$	Contrast
Surprise	137.154 [132.304, 142.094]*	180.893 [175.907, 185.793]*	−43.754 [−46.906, −40.646]*
Sadness	128.319 [123.379, 133.189]*	147.595 [142.71, 152.556]*	−19.311 [−22.343, −16.169]*
Happiness	135.455 [130.544, 140.384]*	173.538 [168.605, 178.442]*	−38.105 [−41.213, −35.021]*
Fear	134.076 [129.218, 139.008]*	155.974 [151.158, 160.997]*	−21.886 [−25.008, −18.867]*
Disgust	166.133 [161.263, 171.101]*	197.035 [192.09, 201.917]*	−30.913 [−34.022, −27.856]*
Anger	153.572 [148.598, 158.344]*	163.772 [158.74, 168.569]*	−10.197 [−13.341, −7.129]*

Distributions are summarized using the median and the 95% HPDI. Asterisks represent contrast where the null value (i.e., 0) is not contained in the 95% HPDI.

TABLE 4 Posterior distribution summaries for the perceived intensity Mask effect as a function of the displayed Emotion.

Emotion	Δ $Mask_{full}$	Δ $Mask_{subtle}$	Contrast
Surprise	−37.287 [−41.586, −32.75]*	−50.215 [−54.675, −45.955]*	12.933 [6.755, 19.033]*
Sadness	−18.173 [−22.324, −13.6]*	−20.443 [−24.766, −16.027]*	2.307 [−3.999, 8.406]
Happiness	−31.522 [−35.959, −27.267]*	−44.677 [−49.076, −40.385]*	13.141 [6.863, 19.188]*
Fear	−10.753 [−15.119, −6.488]*	−33.026 [−37.348, −28.639]*	22.297 [16.116, 28.5]*
Disgust	−22.591 [−26.971, −18.188]*	−39.231 [−43.574, −34.859]*	16.665 [10.384, 22.798]*
Anger	−2.822 [−6.99, 1.658]	−17.58 [−21.988, −13.206]*	14.727 [8.319, 20.722]*

Distributions are summarized using the median and the 95% HPDI. Asterisks represent contrast where the null value (i.e., 0) is not contained in the 95% HPDI.

and the presence of the mask (β = −0.003, SE = 0.003, 95% HPDI = [−0.009, 0.004], $logBF_{01}$ = 5.356).

Similarly, we found no evidence either for the relationship between AQ scores and response *bias* (β = −0.001, SE = 0.001, 95% HPDI = [0.002, 00004], $logBF_{01}$ = 6.06) or for the interaction between AQ and Mask (β = −0.0001, SE = 0.001, 95% HPDI = [−0.002, 0.002], $logBF_{01}$ = 6.30). Similarly, concerning *uncertainty,* we found no evidence for the AQ main effect (β = −0.0006, SE = 0.003 95% HPDI = [−0.006, 0.005], $logBF_{01}$ = 5.16) or for the interaction between AQ and Mask (β = −0.0021, SE = 0.0024, 95% HPDI = [−0.007, 0.003], $logBF_{01}$ = 5).

When considering subtle facial expressions, we found no relationship between AQ scores and response *bias* (β = −0.001, SE = 0.001, 95% HPDI = [−0.003, 0.001], logBF01 = 5.704), and no interaction between AQ scores and the presence of the Mask (β = −0.001, SE = 0.002, 95% HPDI = [−0.004, 0.003], $logBF_{01}$ = 5.524). For the *uncertainty,* we found no AQ main effect (β = −0.002, SE = 0.004, 95% HPDI = [−0.01, 0.006], $logBF_{01}$ = 4.767), and no interaction between AQ and the presence of the Mask (β = 0, SE = 0.004, 95% HPDI = [−0.008, 0.009], $logBF_{01}$ = 4.768).

In relation to the *perceived intensity,* we found no evidence of a main effect of TAS scores (β = −0.24, SE = 0.27, 95% HPDI = [−0.757, 0.296], $logBF_{01}$ = 2.54) or of an interaction between TAS and Mask (β = −0.007, SE = 0.093, 95% HPDI = [−0.188, 0.176], $logBF_{01}$ = 3.94). When considering only the subtle facial expressions, we did not found a TAS effect (β = −0.304, SE = 0.330, 95% HPDI = [−0.967, 0.318], $logBF_{01}$ = 2.325) or the interaction between TAS and Mask (β = −0.097, SE = 0.122, 95% HPDI = [−0.342, 0.133], $logBF_{01}$ = 3.40).

We found the same scenario for the AQ scores. There was no evidence of a main effect of AQ scores (β = −0.331, SE = 0.349, 95% HPDI = [−1.01, 0.355], $logBF_{01}$ = 2.3) or of an interaction between AQ and Mask (β = −0.146, SE = 0.119, 95% HPDI = [−0.38, 0.086], $logBF_{01}$ = 3). When considering only subtle facial expressions, again, we did not find a AQ effect (β = −0.145, SE = 0.421, 95% HPDI = [−0.947, 0.69], $logBF_{01}$ = 2.40) or the interaction between AQ and Mask (β = −0.147, SE = 0.156, 95% HPDI = [−0.444, 0.167], $logBF_{01}$ = 3.02).

Overall, when considering just the subtle facial expressions, we still found evidence for the absence of effect on *perceived intensity, uncertainty*, and *bias*.

Discussion

This study aims to provide a comprehensive description of the types of errors committed when trying to recognize full and subtle basic facial expression expressed by faces covered by a mask. To this end, we asked the participants to respond using a Geneva Emotion Wheel, intending to define their performance according to three indices that we believe could provide a more precise picture of the impact of masks on facial-expression recognition: (1) uncertainty, i.e., the tendency to provide responses associated with different emotional labels without this necessarily being associated with a systematic misattribution

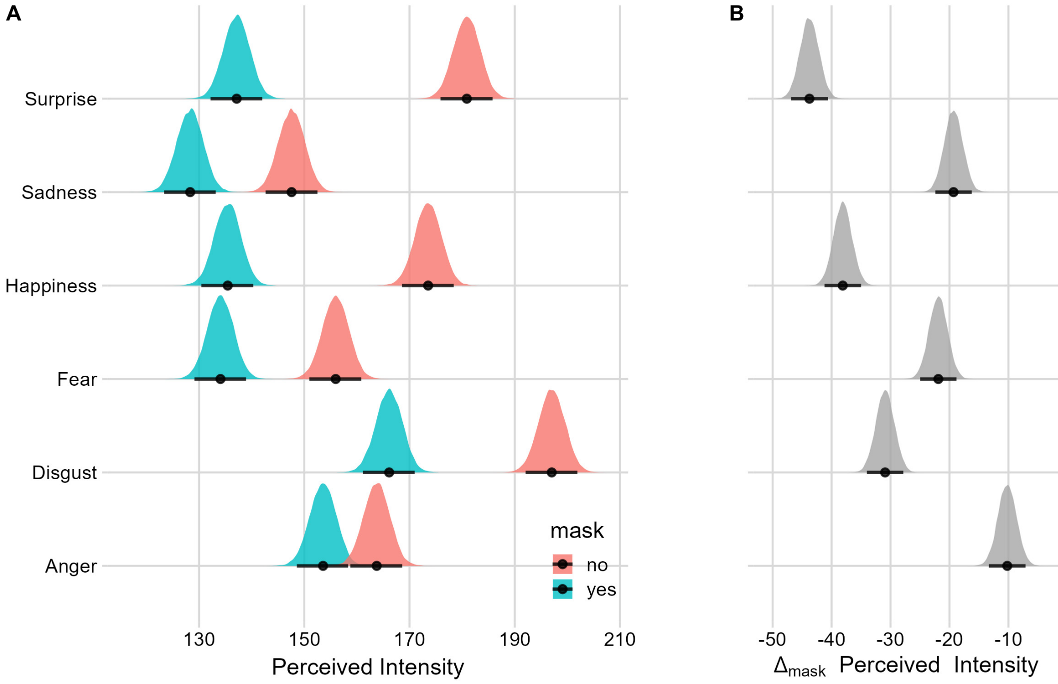

FIGURE 7
Posterior distributions and 95% HPDIs of the *perceived intensity* Mask effect **(A)** Perceived intensity posterior distributions as a function of the Mask condition. **(B)** Posterior distribution of the Mask Δ ($Mask_{yes} - Mask_{no}$).

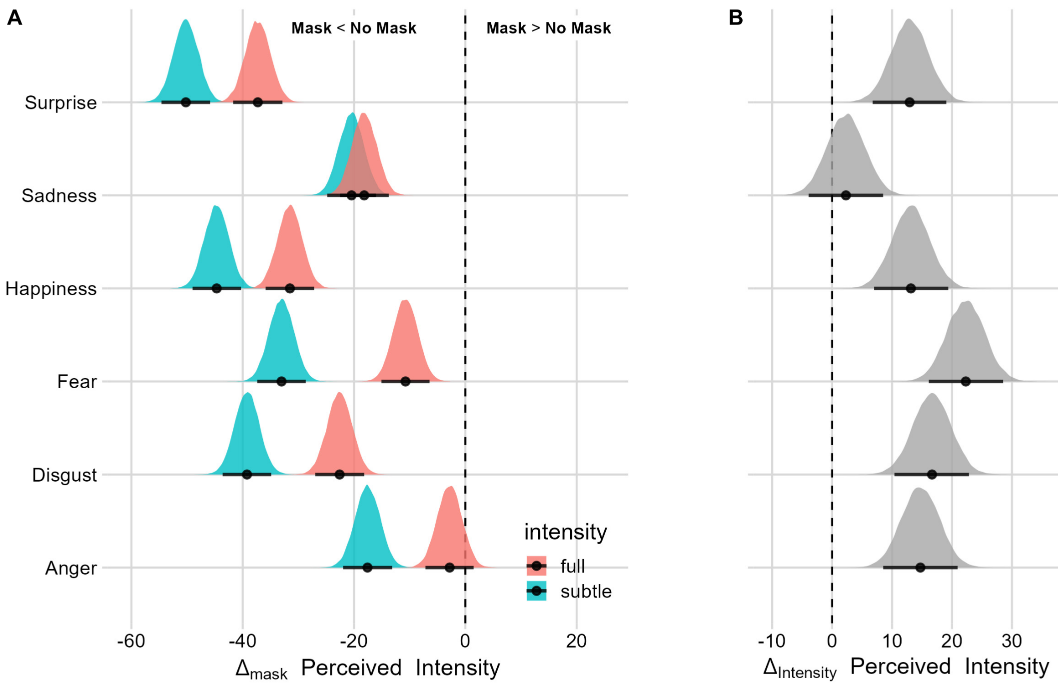

FIGURE 8
Posterior distributions and 95% HPDI of the perceived intensity Facial Expression Intensity Effect **(A)** Perceived intensity posterior distributions as a function of the Facial Expression Intensity condition. **(B)** Posterior distribution of the Facial Expression Intensity Δ (Mask Δ_{full} − Mask Δ_{subtle}).

of emotional expressions; (2) bias, i.e., the systematic error of confusing one emotion with others; and (3) perceived intensity.

Notably and not surprisingly, the uncertainty in the participants' responses (i.e., the amount of spread in responses) increases for *all facial expressions* (except for *fear)* when faces are covered by a mask. However, when considering the intensity of the expression, *subtle expressions of fear* are also associated with an increase in uncertainty. Interestingly, in the study by Carbon (2020), the author measured participants' confidence for each assessment of the facial-expression recognition task on a scale from 1 (very unconfident) to 7 (very confident) and found a large-sized effect for all the expressions tested. Our results dovetail nicely with these previous findings by providing an index that is not based on the subjectively felt confidence about one's assessment but, rather, an objective measure of such confidence (i.e., uncertainty). In brief, we believe that our results align perfectly with these previous findings, while using a more fine-grained performance index (i.e., uncertainty) based on the GEW complex space.

Regarding response bias, our results indicate a tendency to systematically confuse the expression of *disgust* with other emotions (especially anger: see **Figures 2**, **3**) when a face is masked. This result is not surprising considering that the prototypical expression of disgust is characterized by the curling of the nose (in terms of AUs, this corresponds to AU9) and the lifting of the upper lip (AU10). Therefore, diagnostic information is incomplete, or almost completely missing when faces are covered by a mask (in particular, with the use of the N95 mask, which tends to cover not only the mouth region but also the nose completely). This result appears to align with previous studies (Carbon, 2020; Carbon and Serrano, 2021; Ziccardi et al., 2021; Carbon et al., 2022; Kim et al., 2022; Tsantani et al., 2022).

The results relating to the expression of *sadness,* on the other hand, may appear surprising. These, albeit marginally, indicate a reversed bias when faces are covered by a mask (i.e., fostering the correct recognition of sadness expressed by masked faces: see **Figure 3**). Indeed, previous studies (e.g., Carbon, 2020; Carbon and Serrano, 2021; Carbon et al., 2022; Kim et al., 2022) have reported a worsening in the recognition of sadness expressed by a masked face. However, considering the AUs available when a face is masked, the one prototypically associated with sadness is AU1 (i.e., a raising and approaching of the eyebrows). Since no other facial expression of a primary emotion has these characteristics, it seems legitimate to conclude that the presence of a mask may allow a person to focus on the most diagnostic and available information for recognizing sadness. It should be noted that other studies did not observe a decrease in the recognition of sadness when the face was covered by the mask (see Noyes et al., 2021). Indeed, when considering the intensity of the expressions, subtle sad faces are associated with an increase in response bias when faces are covered by masks.

We did not observe an increase/decrease in response bias for the remaining emotions (i.e., *surprise*, *fear, anger*, and *happiness)* as a function of the mask. As far as surprise, fear, and anger are concerned, this result seems in line with the observation that most distinctive information remains available despite the mask covering the face. The eye region is the most important of all three of these expressions. On the other hand, the result relating to happiness is unexpected since the mask hides the mouth and the contraction of the zygomatic muscle that is markedly associated with this expression. However, the mask leaves another diagnostic element visible, namely, that relating to the eyes and the contraction of the orbicular muscle in its external part, which may be sufficient for the correct detection of the expression. It should be noted that, when also considering the expression intensity as a function of the impact of the mask, full-intensity expressions of happiness are associated with a slight response bias, particularly toward the categories of interest and surprise.

Finally, *all the expressions* (especially surprise and happiness) were perceived as less intense when covered by a mask. This finding aligns nicely with previous studies (Pazhoohi et al., 2021; Sheldon et al., 2021; Kastendieck et al., 2022; Langbehn et al., 2022; Ramachandra and Longacre, 2022; Tsantani et al., 2022). Interestingly and with the exception of sadness, we have found that this effect is even more pronounced when the expressions are subtle.

To summarize the main results, the presence of a mask makes the recognition of all primary emotions more demanding (as supported by the "uncertainty" index) regardless of their level of intensity. The one exception is intense fear, which is not subject to this increment of uncertainty as a function of the face mask manipulation. Overall, these findings indicate that face masks reduce diagnostic information for recognizing facial expressions. Moreover, when they do not induce systematic errors of emotion misattribution, they increase uncertainty in observers regarding which emotion the other person is feeling/communicating. The observation that this uncertainty also increases for subtle fear when the face is masked supports our hypothesis that the processing of subtle expressions may be more markedly affected by face masks.

On the other hand, an increase in systematic misattribution errors (i.e., "bias") when the faces are covered by a mask (vs. uncovered) seems to be minimal and mainly concerns the expression of disgust, which is primarily confused with anger. This is so, regardless of the degree of the expression's intensity. To a lesser extent, the full expression of happiness is also confused with interest and surprise, and the subtle expressions of sadness are misinterpreted as fear and anger. Thus, these misattribution errors seem to concern only those expressions that are distinctively conveyed by the (covered) lower portion of the face (i.e., disgust and happiness).

Finally, all the emotions were perceived as less intense, especially when subtle.

Overall, these findings suggest that face masks affect the recognition of emotions differently according to the availability of the diagnostic information distributed over the face. Thus, the emotions mainly conveyed by the lower portion of the face are more likely to be subjected to misattribution errors, while all emotions, especially those conveyed by the upper portion of the face, are associated with a general increase in uncertainty.

Although the present study did not directly investigate the neural basis of expression perception in conditions of mask covering (mainly because of the protracted closure of the department's electroencephalography and neuroimaging laboratories due to the pandemic), we believe some considerations may be helpful to future studies interested in investigating such neural underpinnings.

In particular, we expect that uncertainty - as we have measured it in the present work - could have a neural counterpart, since there is evidence that uncertainty of participants' responses is linked with variability in neural responses (Festa et al., 2021).

What kind of neural responses could present this kind of variability? To provide an answer to this question, we need to consider neural markers of face processing and the most accredited neural model for processing faces and facial expressions. Three principal posterior brain areas are involved in the visual processing of faces (Haxby and Gobbini, 2011; Duchaine and Yovel, 2015; see also Dalrymple et al., 2011), the fusiform face area (FFA), the occipital face area (OFA), and the posterior superior temporal sulcus (pSTS). FFA is considered the main neural substrate of configural-holistic face processing (e.g., Mazard et al., 2006; Schiltz and Rossion, 2006), while pSTS is sensitive to changing features, such as facial expressions (Haxby and Gobbini, 2011; Duchaine and Yovel, 2015). It is reasonable to assume that the mask has an impact on the holistic-configural processing of faces (and therefore on the activation of FFA) and that in the conditions in which the face is covered by the mask, the processing of facial expressions of emotion may be devolved mainly to the OFA and pSTS. However, when a face is covered by a mask, OFA and pSTS have a reduced amount of information available compared to when the face is fully visible. Although at the moment, this is only speculation, it is plausible that the (reduced and partial) diagnostic/distinctive information for emotion recognition when a mask is worn is associated with greater variability of neural responses in these regions, hence, resulting in a decrease in perceptual sensitivity and an increase in the uncertainty of participants' responses (see Festa et al., 2021). At the electrophysiological level, even the most well-known marker of face processing originating from these posterior regions, namely, the N170 event-related potential, could reflect this increase in uncertainty in the form of a latency delay or a greater latency variability.

When the mask covers those features that strongly characterize an expression of emotion, any features still available in the upper portion of the face can induce misattribution errors if they are a diagnostic of other primary emotions. This would seem to be precisely what was observed for the expression of disgust. The only additional secondary feature available when the face is covered is the tension of the inferior eyelid (i.e., AU7), a diagnostic feature of anger. In this case, these misattribution errors would not be primarily associated with increased variability in neuronal responses in the OFA and pSTS but, rather, with the "correct" analysis of the available relevant—but misleading—information.

Finally, the most recent sensorimotor simulation model considers that the involvement of a distributed emotion system during the processing of expressions of emotion supports their recognition (Wood et al., 2016). This system is recruited either directly by the exposure to expressions of emotions or indirectly by the sensorimotor system. The observation that a mask reduces the experienced intensity of emotions suggests that this emotion system is recruited to a lesser extent when the expressions are covered by a mask than when they are completely visible. It is interesting to note that this result, in some respects, mimics the performance of patients with ventromedial prefrontal cortex lesions whose judgment about the intensity of facial expressions does not correspond to the actual intensity of such expressions, unlike patients with other (non-critical) prefrontal lesions and healthy control subjects (Heberlein et al., 2008).

We also expected to observe a relationship between alexithymic and autistic traits assessed by means of the 20-item TAS (Bagby et al., 1994) and the AQ (Baron-Cohen et al., 2001) with the three indices (uncertainty, bias, and perceived intensity). To our knowledge, our study is the first to use a large sample to explore the relationship between alexithymic and autistic traits and performance in emotion recognition as a function of the face mask. Surprisingly, we did not find any evidence of such relations. These results are even more surprising if one considers that the ability to read emotions from the eye region is particularly compromised in several neuropsychiatric disorders, including autism spectrum disorder (e.g., Baron-Cohen et al., 2001). Furthermore, there is evidence that performance on the Reading the Mind in the Eyes Test (RMET) is impaired in alexithymic individuals (Oakley et al., 2016; Rødgaard et al., 2019). These results might suggest that the recognition performance relating to a face's eye area (as in RMET) is not entirely comparable to the recognition performance relating to facial expressions covered by the mask. However, caution is necessary to accept these conclusions definitively. Indeed, the low scores' variability in the questionnaires to measure alexithymic and autistic traits could limit the possibility of observing a relationship between performance and these traits. It is also important to underline that our sample comprises healthy subjects, and in a few cases, we have observed scores above the clinical cut-offs.

Regarding the present study's limitations, we note that due to the safety regulations introduced to prevent exposure to the SARS-COV-2 virus, most studies on this topic (including ours) have, to date, been conducted online. While this has allowed larger numbers of participants to collaborate in the different studies, it is also true that it has allowed only limited control over the experiments' settings. Another limitation concerns the nature of the stimuli presented. More often than not, the facial expressions portraying the targeted effect displayed it in a stereotypical manner and with exaggerated intensity, using photographs of actors who have received instructions regarding which muscles to contract to achieve the desired expression. In everyday life, however, the facial expressions people are confronted with may be different, more sophisticated, less obvious, and therefore, harder to categorize. We tried to overcome these limitations, at least in part, by manipulating the expressions' intensity (full vs. subtle), demonstrating that the processing of subtle expressions is even more compromised by face masks. It must also be stressed that many studies had higher numbers of female than male participants, making it difficult to carry out gender comparisons. Our study, too, is subject to this limitation, as most of the participants were women. It is not clear how this gender unbalance could have influenced the results of our and previous studies. We imagine two alternative scenarios, both based on experimental evidence: We see two possible and opposite scenarios: (1) Since it is known that women are more expressive than men (e.g., Kring and Gordon, 1998), more accurate in processing emotional expressions (e.g., Hoffmann et al., 2010) and more empathetic (e.g., Singer and Lamm, 2009), this gender unbalance could lead to an underestimation of the impact of face masks on the ability to recognize facial expressions; and (2) On the other side, it has been proposed that women are better at recognizing emotional expressions because they use a more embodied route (see, e.g., Stel and van Knippenberg, 2008), which could be strongly affected by the covering of the lower part of the face. This evidence might lead to opposite conclusions that samples made almost entirely from women can produce an overestimation of the impact of face masks on the ability to recognize facial expressions.

Another possible limitation is based on the knowledge about neural models of face processing: When processing expressions of emotion, the activation would further propagate throughout the dorsal pathway to more anterior regions (anterior superior temporal sulcus, aSTS, and inferior frontal gyrus; Duchaine and Yovel, 2015). In addition, sensorimotor and embodied simulation models assign a central role to the frontal operculum, the ventromedial prefrontal cortex, the supplementary motor area, and the emotion system (Gallese, 2005; Wood et al., 2016; Gallese and Sinigaglia, 2018). It is known that these brain areas are more strongly recruited by dynamic (rather than static) facial expressions (Duchaine and Yovel, 2015; Pitcher and Ungerleider, 2021). From this point of view, it is possible that, in ecological conditions, the misattribution errors and participants' uncertainty observed in our study may be attenuated by the additional information conveyed by the movement of the facial muscles involved in the facial expression.

To conclude, we also believe that the present study has some merits. First of all, the introduction of the GEW to collect the participants' responses probably reduced the possibility of ceiling effects. It also allowed us to identify more clearly the misattribution errors that may involve secondary emotions (for example happiness being confused with interest as well as a surprise). Furthermore, thanks to the use of the GEW's complex space, we were able to compute an objective index of uncertainty in the participants' responses: one which seems to correspond to the results regarding response confidence found in previous studies (Carbon, 2020). In general, using this tool to gather participants' answers allowed us to obtain rich information about the perception-space of facial expressions of emotion in terms of bias, uncertainty, and perceived intensity. This though a single click for each expression presented. These indices permitted us to clarify that the emotions conveyed mainly by the lower portion of the face (covered by the mask) are more likely to be associated with response bias. All emotions, including those characterized by elements peculiar to the upper portion of the face (not covered), are subject to increased response uncertainty. Furthermore, when covered by a mask, all emotions are perceived as less intense, and this is particularly so when they are subtly expressed.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: Open Science Framework; https://osf.io/e2kcw/.

Ethics statement

The studies involving human participants were reviewed and approved by Comitato Etico Della Ricerca Psicologica—Area 17—Università degli Studi di Padova. The patients/participants provided their written informed consent to participate in this study.

Author contributions

PS developed the study concept. AV programmed the experiment and prepared the stimuli. AV and CR gathered the data. FG performed the data analysis, while PS and FG interpreted the data. All authors contributed to the study design, drafted the manuscript, and approved the final version for submission.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.956832/full#supplementary-material

References

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., and Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behav. Res. Methods* 52, 388–407. doi: 10.3758/s13428-019-01237-x

Bagby, R. M., Parker, J. D. A., and Taylor, G. J. (1994). The twenty-item Toronto Alexithymia scale I. Item selection and cross-validation of the factor structure. *J. Psychosom. Res.* 38, 23–32. doi: 10.1016/0022-3999(94)90005-1

Bani, M., Russo, S., Ardenghi, S., Rampoldi, G., Wickline, V., Nowicki, S., et al. (2021). Behind the Mask: Emotion Recognition in Healthcare Students. *Med. Sci. Educ.* 31, 1273–1277. doi: 10.1007/s40670-021-01317-8

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., and Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Malesand Females, Scientists and Mathematicians. *J. Autism Dev. Disord.*13, 5–17 doi: 10.1023/a:1005653411471

Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., et al. (2009). Generalized linear mixed models: A practical guide for ecology and evolution. *Trends Ecol. Evol.* 24, 127–135. doi: 10.1016/j.tree.2008.10.008

Bürkner, P.-C. (2017). brms: An R Package for Bayesian Multilevel Models Using Stan. *J. Stat. Softw. Artic.* 80, 1–28. doi: 10.18637/jss.v080.i01

Bürkner, P. C. (2018). Advanced Bayesian Multilevel Modeling with the R Package brms. *R J.* 10, 395–411. doi: 10.32614/RJ-2018-017

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: An online study on face covering. *Sci. Rep.* 11:2601. doi: 10.1038/s41598-021-81780-w

Calvo, M. G., and Fernández-Martín, A. (2013). Can the eyes reveal a person's emotions? Biasing role of the mouth expression. *Motiv. Emot.* 37, 202–211. doi: 10.1007/s11031-012-9298-1

Calvo, M. G., Fernández-Martín, A., and Nummenmaa, L. (2014). Facial expression recognition in peripheral versus central vision: Role of the eyes and the mouth. *Psychol. Res.* 78, 180–195. doi: 10.1007/s00426-013-0492-x

Carbon, C.-C. (2020). Wearing Face Masks Strongly Confuses Counterparts in Reading Emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C.-C., Held, M. J., and Schütz, A. (2022). Reading Emotions in Faces With and Without Masks Is Relatively Independent of Extended Exposure and Individual Difference Variables. *Front. Psychol.* 13:856971. doi: 10.3389/fpsyg.2022.856971

Carbon, C.-C., and Serrano, M. (2021). The Impact of Face Masks on the Emotional Reading Abilities of Children A Lesson From a Joint School University Project. *Ipercept* 12:204166952110382. doi: 10.1177/20416695211038265

Coyne, A. K., Murtagh, A., and McGinn, C. (2020). "Using the Geneva Emotion Wheel to Measure Perceived Affect in Human-Robot Interaction," in *Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction*, (Cambridge: ACM), 491–498.

Cremers, J., and Klugkist, I. (2018). One Direction? A Tutorial for Circular Data Analysis Using R With Examples in Cognitive Psychology. *Front. Psychol.* 9:2040. doi: 10.3389/fpsyg.2018.02040

Dalrymple, K. A., Oruç, I., Duchaine, B., Pancaroglu, R., Fox, C. J., Iaria, G., et al. (2011). The anatomic basis of the right face-selective N170 IN acquired prosopagnosia: A combined ERP/fMRI study. *Neuropsychologia* 49, 2553–2563. doi: 10.1016/j.neuropsychologia.2011.05.003

Duchaine, B., and Yovel, G. (2015). A Revised Neural Framework for Face Processing. *Annu. Rev. Vis. Sci.* 1, 393–416. doi: 10.1146/annurev-vision-082114-035518

Ekman, P., and Friesen, W. V. (1978). *Facial Action Coding System. Environmental Psychology and Nonverbal Behavior*. doi: 10.1037/t27734-000

Evans, M., Hastings, N., and Peacock, B. (2011). "von Mises Distribution," in *Statistical Distributions*, (eds) M. Evans., N. Hastings., and, B. Peacock (New York, NY: Wiley), 191–192.

Festa, D., Aschner, A., Davila, A., Kohn, A., and Coen-Cagli, R. (2021). Neuronal variability reflects probabilistic inference tuned to natural image statistics. *Nat. Commun.* 12:3635. doi: 10.1038/s41467-021-23838-x

Fitousi, D., Rotschild, N., Pnini, C., and Azizi, O. (2021). Understanding the Impact of Face Masks on the Processing of Facial Identity, Emotion, Age, and Gender. *Front. Psychol.* 12:743793. doi: 10.3389/fpsyg.2021.743793

Gallese, V. (2005). Embodied Simulation: From Neurons to Phenomenal Experience. *Phenomenol. Cogn. Sci.* 4, 23–48. doi: 10.1007/s11097-005-4737-z

Gallese, V., and Sinigaglia, C. (2018). "Embodied Resonance," in *The Oxford Handbook of 4E Cognition*, (eds) A. Newen., L. Bruin., S. De Gallagher. (Oxford: Oxford University Press)doi: 10.1093/oxfordhb/9780198735410.013.22

Gelman, A. (2006). Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). *Bayesian Anal.* 1, 515–534. doi: 10.1214/06-BA117A

Gelman, A., and Rubin, D. B. (1992). Inference from Iterative Simulation Using Multiple Sequences. *Statistical Sci.* 7, 457–472. doi: 10.1214/ss/1177011136

Gelman, A., Simpson, D., and Betancourt, M. (2017). The Prior Can Often Only Be Understood in the Context of the Likelihood. *Entropy* 19:555. doi: 10.3390/e19100555

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking Emotions: Face Masks Impair How We Read Emotions. *Front. Psychol.* 12:669432. doi: 10.3389/fpsyg.2021.669432

Grahlow, M., Rupp, C., and Dernt, B. (2021). The impact of face masks on emotion recognition performance and perception of threat. *psyarxiv* [preprint]. doi: 10.31234/osf.io/6msz8

Grenville, E., and Dwyer, D. M. (2022). Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion. *Cogn. Res. Princ. Implic.* 7:15. doi: 10.1186/s41235-022-00366-w

Grundmann, F., Epstude, K., and Scheibe, S. (2020). Face masks reduce emotion-recognition accuracy and perceived closeness. *psyarxiv* [preprint]. doi: 10.31234/osf.io/xpzs3

Haxby, J. V., and Gobbini, M. I. (2011). Distributed Neural Systems for Face Perception. in *The Oxford Handbook of Face Perception*, (eds) M. H. Johnson., J. V. Haxby, (Oxford: Oxford University Press) doi: 10.1093/oxfordhb/9780199559053.013.0006

Heberlein, A. S., Padon, A. A., Gillihan, S. J., Farah, M. J., and Fellows, L. K. (2008). Ventromedial Frontal Lobe Plays a Critical Role in Facial Emotion Recognition. *J. Cogn. Neurosci.* 20, 721–733. doi: 10.1162/jocn.2008.20049

Hoffmann, H., Kessler, H., Eppel, T., Rukavina, S., and Traue, H. C. (2010). Expression intensity, gender and facial emotion recognition: Women recognize only subtle facial emotions better than men. *Acta Psychol.* 135, 278–283. doi: 10.1016/j.actpsy.2010.07.012

Kang, J., Kang, S., Jeong, E., and Kim, E.-H. (2021). Age and cultural differences in recognitions of emotions from masked faces among koreans and americans. *Int. J. Environ. Res. Public Health* 18:10555. doi: 10.3390/ijerph181910555

Kastendieck, T., Zillmer, S., and Hess, U. (2022). (Un)mask yourself! Effects of face masks on facial mimicry and emotion perception during the COVID-19 pandemic. *Cogn. Emot.* 36, 59–69. doi: 10.1080/02699931.2021.1950639

Kim, G., Seong, S. H., Hong, S.-S., and Choi, E. (2022). Impact of face masks and sunglasses on emotion recognition in South Koreans. *PLoS One* 17:e0263466. doi: 10.1371/journal.pone.0263466

Kret, M. E., and de Gelder, B. (2012). Islamic Headdress Influences How Emotion is Recognized from the Eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Kret, M. E., and Fischer, A. H. (2018). Recognition of facial expressions is moderated by Islamic cues. *Cogn. Emot.* 32, 623–631. doi: 10.1080/02699931.2017.1330253

Kret, M. E., Maitner, A. T., and Fischer, A. H. (2021). Interpreting Emotions From Women With Covered Faces: A Comparison Between a Middle Eastern and Western-European Sample. *Front. Psychol.* 12:620632. doi: 10.3389/fpsyg.2021.620632

Kring, A. M., and Gordon, A. H. (1998). Sex differences in emotion: Expression, experience, and physiology. *J. Pers. Soc. Psychol.* 74, 686–703. doi: 10.1037/0022-3514.74.3.686

Kruschke, J. K., and Liddell, T. M. (2018). The Bayesian New Statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a Bayesian perspective. *Psychon. Bull. Rev.* 25, 178–206. doi: 10.3758/s13423-016-1221-4

Langbehn, A. T., Yermol, D. A., Zhao, F., Thorstenson, C. A., and Niedenthal, P. M. (2022). Wearing N95, Surgical, and Cloth Face Masks Compromises the Perception of Emotion. *Affect. Sci.* 3, 105–117 doi: 10.1007/s42761-021-00097-z

Lau, W. K. (2021). Face Masks Bolsters the Characteristics From Looking at a Face Even When Facial Expressions Are Impaired. *Front. Psychol.* 12:704916. doi: 10.3389/fpsyg.2021.704916

Liedtke, C., Kohl, W., Kret, M. E., and Koelkebeck, K. (2018). Emotion recognition from faces with in- and out-group features in patients with depression. *J. Affect. Disord.* 227, 817–823. doi: 10.1016/j.jad.2017.11.085

Lundqvist, D., Flykt, A., and Öhman, A. (1998). Karolinska directed emotional faces. *Cogn. Emot.* 22, 1094–1118

Maiorana, N., Dini, M., Poletti, B., Tagini, S., Rita Reitano, M., Pravettoni, G., et al. (2022). The Effect of Surgical Masks on the Featural and Configural Processing of Emotions. *Int. J. Environ. Res. Public. Health* 19:2420. doi: 10.3390/ijerph19042420

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Mazard, A., Schiltz, C., and Rossion, B. (2006). Recovery from adaptation to facial identity is larger for upright than inverted faces in the human occipito-temporal cortex. *Neuropsychologia* 44, 912–922. doi: 10.1016/j.neuropsychologia.2005.08.015

McCrackin, S. D., Capozzi, F., Mayrand, F., and Ristic, J. (2022). Face masks impair basic emotion recognition: Group effects and individual variability. *Soc. Psychol.* doi: 10.1027/1864-9335/a000470 [Epub ahead of print].

Nakagawa, S., Poulin, R., Mengersen, K., Reinhold, K., Engqvist, L., Lagisz, M., et al. (2015). Meta-analysis of variation: Ecological and evolutionary applications and beyond. *Methods Ecol. Evol.* 6, 143–152. doi: 10.1111/2041-210X.12309

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L. H., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Oakley, B. F. M., Brewer, R., Bird, G., and Catmur, C. (2016). Theory of mind is not theory of emotion: A cautionary note on the Reading the Mind in the Eyes Test. *J. Abnorm. Psychol.* 125:818. doi: 10.1037/abn0000182

Parada-Fernández, P., Herrero-Fernández, D., Jorge, R., and Comesaña, P. (2022). Wearing mask hinders emotion recognition, but enhances perception of attractiveness. *Personal. Individ. Differ.* 184:111195. doi: 10.1016/j.paid.2021.111195

Pavlova, M., and Sokolov, A. (2022). Reading Covered Faces. *Cereb. Cortex* 32, 249–265. doi: 10.1093/cercor/bhab311

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Pitcher, D., and Ungerleider, L. G. (2021). Evidence for a Third Visual Pathway Specialized for Social Perception. *Trends Cogn. Sci.* 25, 100–110. doi: 10.1016/j.tics.2020.11.006

R Core Team (2022). *R: A language and Environment for Statistical Computing*. Vienna: R Core Team.

Ramachandra, V., and Longacre, H. (2022). Unmasking the psychology of recognizing emotions of people wearing masks: The role of empathizing, systemizing, and autistic traits. *Personal. Individ. Differ.* 185:111249.

Rigby, R. A., and Stasinopoulos, D. M. (2005). Generalized additive models for location, scale and shape (with discussion). *J. R. Stat. Soc. Ser. C Appl. Stat.* 54, 507–554. doi: 10.1111/j.1467-9876.2005.00510.x

Rødgaard, E.-M., Jensen, K., and Mottron, L. (2019). An opposite pattern of cognitive performance in autistic individuals with and without alexithymia. *J. Abnorm. Psychol.* 128, 735–737. doi: 10.1037/abn0000408

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: Implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Schad, D. J., Vasishth, S., Hohenstein, S., and Kliegl, R. (2020). How to capitalize on a priori contrasts in linear (mixed) models: A tutorial. *J. Mem. Lang.* 110:104038. doi: 10.1016/j.jml.2019.104038

Scherer, K. R. (2005). What are emotions? And how can they be measured?. *Soc. Sci. Inf.* 44, 695–729. doi: 10.1177/0539018405058216

Scherer, K. R., Shuman, V., Fontaine, J. R. J., and Soriano, C. (2013). "The GRID meets the Wheel: Assessing emotional feeling via self-report1," in *Components of Emotional Meaning*, eds J. R. J. Fontaine, K. R. Scherer, and C. Soriano (Oxford: Oxford University Press), 281–298. doi: 10.1093/acprof:oso/9780199592746.003.0019

Schiltz, C., and Rossion, B. (2006). Faces are represented holistically in the human occipito-temporal cortex. *NeuroImage* 32, 1385–1394. doi: 10.1016/j.neuroimage.2006.05.037

Schneider, J., Sandoz, V., Equey, L., Williams-Smith, J., Horsch, A., and Bickle Graz, M. (2022). The Role of Face Masks in the Recognition of Emotions by Preschool Children. *JAMA Pediatr.* 176, 96–98. doi: 10.1001/jamapediatrics.2021.4556

Sheldon, K. M., Goffredi, R., and Corcoran, M. (2021). The Glow Still Shows: Effects of Facial Masking on Perceptions of Duchenne Versus Social Smiles. *Perception* 50, 720–727. doi: 10.1177/03010066211027052

Siegert, I., Böck, R., Vlasenko, B. V., and Wendemuth, A. (2011). "Appropriate emotional labelling of non-acted speech using basic emotions, geneva emotion wheel and self assessment manikins,"in *IEEE International Conference on Multimedia and Expo (ICME)*, Barcelona: IEEE

Singer, T., and Lamm, C. (2009). The Social Neuroscience of Empathy. *Ann. N.Y Acad. Sci.* 1156, 81–96. doi: 10.1111/j.1749-6632.2009.04418.x

Stan Development Team (2022). *Stan Modeling Language Users Guide and Reference Manual, 2.21.0*. Available online at: https://mc-stan.org.

Stel, M., and van Knippenberg, A. (2008). The role of facial mimicry in the recognition of affect. *Psychol. Sci.* 19, 984–985. doi: 10.1111/j.1467-9280.2008.02188.x

Trainin, N., and Yeshurun, Y. (2021). Reading the mind with a mask? Improvement in reading the mind in the eyes during the COVID-19 pandemic. *Emotion* 21, 1801–1806. doi: 10.1037/emo0001014

Tran, V. (2004). *The influence of emotions on decision-making processes in management teams*. Genéve: Faculté de Psychologie et des Sciences de L'Éducation, Université de Genéve.

Tsantani, M., Podgajecka, V., Gray, K. L. H., and Cook, R. (2022). How does the presence of a surgical face mask impair the perceived intensity of facial emotions? *PLoS One* 17:e0262344. doi: 10.1371/journal.pone.0262344

Vaughan, B. (2011). *Naturalistic Emotional Speech Corpora with Large Scale Emotional Dimension Ratings*. Ph. D. thesis, Dublin: Dublin Institute of Technology

Vehtari, A., Gelman, A., and Gabry, J. (2017). Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. *Stat. Comput.* 27, 1413–1432. doi: 10.1007/s11222-016-9696-4

Wagenmakers, E.-J., Lodewyckx, T., Kuriyal, H., and Grasman, R. (2010). Bayesian hypothesis testing for psychologists: A tutorial on the Savage–Dickey method. *Cognit. Psychol.* 60, 158–189. doi: 10.1016/j.cogpsych.2009.12.001

Wegrzyn, M., Bruckhaus, I., and Kissler, J. (2015). Categorical Perception of Fear and Anger Expressions in Whole, Masked and Composite Faces. *PLoS One* 10:e0134790. doi: 10.1371/journal.pone.0134790

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Wood, A., Rychlowska, M., Korb, S., and Niedenthal, P. (2016). Fashioning the Face: Sensorimotor Simulation Contributes to Facial Expression Recognition. *Trends Cogn. Sci.* 20, 227–240. doi: 10.1016/j.tics.2015.12.010

Zheng, L., and Xia, M. (2012). Emotional eye movement generation based on Geneva Emotion Wheel for virtual agents. *J. Vis. Lang. Comput.* 23, 299–310.

Ziccardi, S., Crescenzo, F., and Calabrese, M. (2021). What Is Hidden behind the Mask?" Facial Emotion Recognition at the Time of COVID-19 Pandemic in Cognitively Normal Multiple Sclerosis Patients. *Diagnostics* 12:47.

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How facial masks alter the interaction of gaze direction, head orientation, and emotion recognition

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The COVID-19 pandemic has altered the way we interact with each other: mandatory mask-wearing obscures facial information that is crucial for emotion recognition. Whereas the influence of wearing a mask on emotion recognition has been repeatedly investigated, little is known about the impact on interaction effects among emotional signals and other social signals. Therefore, the current study sought to explore how gaze direction, head orientation, and emotional expression interact with respect to emotion perception, and how these interactions are altered by wearing a face mask. In two online experiments, we presented face stimuli from the Radboud Faces Database displaying different facial expressions (anger, fear, happiness, neutral, and sadness), gaze directions (−13°, 0°, and 13°), and head orientations (−45°, 0°, and 45°) – either without (Experiment 1) or with mask (Experiment 2). Participants categorized the displayed emotional expressions. Not surprisingly, masks impaired emotion recognition. Surprisingly, without the mask, emotion recognition was unaffected by averted head orientations and only slightly affected by gaze direction. The mask strongly interfered with this ability. The mask increased the influence of head orientation and gaze direction, in particular for the emotions that were poorly recognized with mask. The results suggest that in case of uncertainty due to ambiguity or absence of signals, we seem to unconsciously factor in extraneous information.

KEYWORDS

emotion perception, facial expression recognition, gaze direction, head orientation, face masks

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has posed a global challenge of enormous magnitude causing high monetary and non-monetary costs and severely impacting physical as well as mental health worldwide (Pedrosa et al., 2020; Rajkumar, 2020; Vindegaard and Benros, 2020; Xiong et al., 2020; Brodeur et al., 2021;

Wessels et al., 2022; World Health Organization [WHO], 2022). Mandatory contact restrictions and mask wearing inevitably affect the nature of our social interactions. Not only has the total number of daily face-to-face interactions decreased, but we often allow for larger interpersonal distance contrary to our natural preference (Welsch et al., 2020, 2021). Moreover, a mask frequently covers the lower part of the face, including the nose, mouth, and chin, and thereby deprives us of facial cues that are crucial for emotion recognition. Emotions are an inherent part of social interactions, and their causes, functions and consequences are interpersonally shaped (Parkinson, 1996; Van Kleef, 2009; Van Kleef et al., 2016). Thus, the quality and success of social interactions crucially depends on emotional competences including emotion recognition abilities (Lopes et al., 2004, 2005; Mayer et al., 2008). How well do we recognize emotions under such conditions of reduced cue availability? To answer this question, we distinguish between partial occlusion of the face and effects of face aversion. How does the complete absence of facial signals of the lower face due to mask wearing alter emotion perception? And how do more traditional restrictions, such as the altered visibility or salience of facial signals due to gaze or head deflection (a disruption of horizontal symmetry) affect emotion recognition? We have encountered the latter case all along. We are rarely confronted with faces perfectly aligned with our viewing direction. Only in portrait photos do faces gaze straight, but they are overwhelmingly chosen as stimuli in studies of emotion recognition – as opposed to faces viewed from the side and/or with averted gaze. The systematic occlusion of all facial features below the eyes, in contrast, is novel. In the current paper, we aim to settle these questions by first investigating emotion recognition under conditions of natural information reduction by varying gaze direction and head orientation, secondly by examining the additional influence of mask wearing, and finally by looking at potential interactions of such effects. We hypothesized that wearing a face mask alters the effects of gaze direction and head orientation.

Emotion-specific emotion recognition

It can be assumed that such cue reductions affect emotion recognition to varying degrees depending on the displayed emotion, as each emotion has been associated with characteristic facial features, and respective facial areas that carry the information (Ekman, 2017). The present study includes the following four basic emotions, since these are found in almost all approaches: *anger*, *fear*, *sadness*, and *happiness* (Ortony and Turner, 1990; Tracy and Randles, 2011), all of which differ systematically from the baseline *neutral* facial expression. Each of these emotions has been related to a prototypical expression composed of signals from both the eye and the mouth region (Ekman and Friesen, 1978; Ekman, 2017). In addition to the availability of characteristic features, their distinctiveness and visual salience are also important for relative recognition advantages. The more distinctive and salient a facial feature is for a given emotion, the easier the latter can be recognized in isolation (Calvo and Nummenmaa, 2008). The recognition advantage for happiness, for example, is attributed to the distinctiveness and visual salience of the smiling mouth (Calvo and Nummenmaa, 2008; Calvo et al., 2014). For other emotions, an association with one facial region is less stringent. Indications of which facial areas are most diagnostic for the emotions investigated in this study are based on different approaches. Such approaches include tracking eye-movements during emotion recognition (e.g., Eisenbarth and Alpers, 2011; Schurgin et al., 2014), manipulating the visibility of facial information through different techniques (e.g., Smith et al., 2005; Nusseck et al., 2008; Blais et al., 2012; Wegrzyn et al., 2017), or presenting different facial parts in isolation (e.g., Calvo et al., 2014). Since these approaches differ in stimulus material and task conditions, differences are to be expected. The process of emotion recognition is probably different when the access of information is limited as compared to when all information is available and eye-movements are tracked. One facial manipulation technique is the Bubbles technique developed by Gosselin and Schyns (2001), in which faces are seen through a mask containing small holes of variable size, the so-called bubbles. Changing the location of the holes allows to identify the face region most relevant for the recognition of a given emotion. Using this technique, Blais et al. (2012), for instance, demonstrated that the mouth region is the most informative facial area for the discrimination of facial expressions. Wegrzyn et al. (2017) used a similar technique – sequentially uncovering a mask consisting of multiple tiles – but reported different results: Eyes and mouth were both important, and their relative importance depended on the emotion presented. Recognition of sad, fearful, and angry faces benefited from information about the upper face, recognition of happy and disgusted faces from information about the lower face. In sum, the literature on emotion recognition suggests a clear prioritization of the mouth region for happiness (e.g., Nusseck et al., 2008), and a clear prioritization of the eye region for anger (e.g., Bombari et al., 2013). As for sadness and fear, some evidence suggests that the eye region is more important than the mouth region for both sadness (e.g., Eisenbarth and Alpers, 2011) and fear (e.g., Bassili, 1979). Other authors suggest that eye and mouth regions are equally important for fear (e.g., Schurgin et al., 2014) as well as for sadness (e.g., Calvo et al., 2014).

How exactly these mimic signals are processed in emotion recognition – that is, the relative contribution of configural and featural information – is still up for debate. A study by Bombari et al. (2013) suggests that, in general, configural processing is more relevant than featural processing for emotion recognition, but their relative contribution differs among emotions.

Further clues as to how much the individual emotions are affected by covering the lower part of the face can be drawn from research on the impact of naturally occurring coverings such as a niqāb (Fischer et al., 2012; Kret and de Gelder, 2012; Kret et al., 2021). In terms of emotion recognition performance, results showed that the recognition of sadness and happiness was clearly impaired when only seeing the eyes vs. the whole face. In contrast anger and fear were recognized equally well in both conditions (Kret and de Gelder, 2012). Note that in the eyes-only condition, the eyebrows were not visible, which is the case, however, when wearing a face mask. Moreover, emotion perception from the eyes was also influenced by the type of face covering when comparing a niqaāb with a cap and a scarf or censoring black bars (Kret and de Gelder, 2012; Kret et al., 2021). This suggests that the impact of a face mask on emotion recognition may differ from that of a niqaāb or other face coverings, since it is tied to a different affective context. We presume that, in general, also other contextual factors such as gaze direction gain more influence in emotion recognition the more the face is obscured.

The impact of gaze direction and head orientation on emotion recognition

There is more to emotion perception than just the prototypical facial expression. Emotion is a complex, multimodal phenomenon which is influenced by contextual cues. Such cues can come from other perceptual modalities, such as voice (de Gelder and Vroomen, 2000), leading to multisensory interactions (Adams et al., 2010b, 2017; Adams and Nelson, 2011). They can also come from other channels, remaining within the visual modality (Adams et al., 2010b, 2017; Adams and Nelson, 2011), such as body posture (Aviezer et al., 2008; Hassin et al., 2013) or other *extraneous* cues. In particular, due to anatomical conditions of the head and the face, the perception of facial expressions is inseparably linked with the perception of gaze direction and head orientation, resulting in observable interaction effects. We will call this type of emotion perception, which is open to influences and capable of interactions, *integrative* emotion perception.

Within *integrative* emotion perception, gaze direction and head orientation play a key role. Gaze may act as an indicator of attention or as a behavioral component in the processing of facial expressions. Whereas direct gaze seems to hold attention on the face that is viewed, averted gaze seems to shift it away (Senju and Hasegawa, 2005; Bindemann et al., 2008). Attention facilitates face processing and averted attention impairs it (Senju and Hasegawa, 2005; Bindemann et al., 2008; McCrackin and Itier, 2019). There are studies reporting a more accurate recognition performance with direct gaze compared to averted gaze, which, however, also depends on other features of the performer, the observer, and the task (Bindemann et al., 2008; Campbell et al., 2017). Strategically, gaze can complement emotional expression based on an underlying shared meaning. As suggested by the *compound social cues approach*, a composite social cue stimulus is generated, which gains a processing advantage over more reduced signals (Adams et al., 2010a, 2017; Adams and Nelson, 2011; Adams and Kveraga, 2015). According to the *shared signal hypothesis*, gaze direction and facial expression share underlying motivational tendencies of approach and avoidance (Adams et al., 2003, 2006; Adams and Kleck, 2005), and congruent pairings of gaze direction and facial expression are perceived as more intense and are processed more efficiently than incongruent pairings (Adams and Kleck, 2003, 2005; Adams and Franklin, 2009; Benton, 2010; Adams and Nelson, 2011). However, these interactions have been shown to be quite stimulus- and task-dependent (Bindemann et al., 2008; Ricciardelli et al., 2016; Caruana et al., 2019). Furthermore, gaze can also provide relevant contextual cues about target and source of an emotion, which is particularly significant in the context of threat signals, such as anger and fear (Adams and Franklin, 2009). Combinations of anger and direct gaze or fear and averted gaze are of greater ecological relevance than other possible combinations because they provide information about the target and the source of a threat. Such combinations may lead to both increased salience and more efficient processing (Adams and Kleck, 2003; Adams et al., 2003; Putman et al., 2006; Tipples, 2006; Adams and Franklin, 2009; Adams and Kveraga, 2015; El Zein et al., 2015). This could lead to recognition advantages, depending on the prevalence and nature of interaction effects. However, we are less interested to compare different combinations of facial expression and gaze direction, but rather focus on the effect of averted versus direct gaze on the ability to recognize emotions. Here gaze direction can act as an indicator of attention, rather than a behavioral component. The extent of integrative processing of gaze direction and facial expression appears to be modulated by signal discriminability, with greater interaction potential when facial expressions are less distinct (Ganel et al., 2005; Graham and LaBar, 2007, 2012).

With regard to the role of head orientation, it points to the likely focus of attention and thereby carries information about the personal relevance of signals (Hess et al., 2007; Bublatzky et al., 2017). Thus, the head can modulate the signal value and influence signal processing. Faces directed at the observer are perceived as more relevant compared to averted faces (Hess et al., 2007; Bublatzky et al., 2017), and the direction of the head can be assumed to be related to the signal strength of facial expressions as a function of how much to the side the head is turned and limits the visibility of the mimic signals. As far as the emotion recognition performance is concerned, however, the data on the influence of head orientation is less clear than that on the influence of gaze direction, at least as far as the half profile (±45°) is concerned. Hess et al. (2007) who compared decoding accuracy of facial expressions presented in frontal view and 3/4 profile view reported better recognition performance for anger and neutral expressions with a frontally oriented face compared to a laterally oriented face. They also found a tendency toward better recognition performance for fear with a laterally oriented face compared to a frontally oriented face. The recognition of happiness and sadness, in contrast, was not affected by head orientation (Hess et al., 2007). Comparing emotion recognition of facial expressions presented in frontal and in profile view, a previous study by Surcinelli et al. (2021) found that fear, anger, and sadness were better recognized in frontal view compared to profile view whereas there was no difference in the recognition of surprise, disgust, happiness, and neutrality. Taken together, head aversion generally tends to impair emotion recognition, depending on the emotion and depending on how far the head is turned to the side.

Gaze direction and head orientation are also perceptually interlinked, as perception of gaze direction involves the integration of head orientation and the position of the eyes relative to the head (Langton, 2000; Seyama and Nagayama, 2005; Loomis et al., 2008; West, 2013; Sweeny and Whitney, 2017). The processing of the relative eye position appears to be largely based on relational processing of different components of the eye region (e.g., iris-eccentricity, Todorović, 2006, 2009) rather than relying on configural processing of the entire face (Jenkins and Langton, 2003; Schwaninger et al., 2005; Harari et al., 2016). Head orientation is mainly estimated on the basis of the deviation of the head shape from bilateral symmetry, and the deviation of the nose orientation from the vertical center (Wilson et al., 2000). Note that turning the head also occludes areas of the face, which results in critical information loss with larger head rotations. When the orientation of the head is difficult to discern, nose orientation seems to be especially relevant (Wilson et al., 2000). Overall, human perception can provide relatively precise estimates of gaze direction and also head orientation, as long as the head is not deflected too much (Langton et al., 2000; Wilson et al., 2000; Symons et al., 2004). However, both lateral gaze and head deviations from the center are sometimes greatly overestimated (Anstis et al., 1969; Loomis et al., 2008; Otsuka et al., 2016; Alais et al., 2018). The accuracy of estimates is influenced by interaction effects between gaze direction and head orientation. Hecht et al. (2021) have found that when head orientation differs by more than 10° relative to gaze direction, gaze direction exerts a clear attraction effect on the perceived head orientation, that is, the perceived head orientation is shifted in the direction of the given gaze. In contrast, when gaze remains directed toward a frontal target, turning the head to the left or right pushes perceived gaze direction in the opposite direction, what is called a repulsion effect (Gamer and Hecht, 2007; Todorović, 2009; Hecht et al., 2021).

To date, emotional facial expression, gaze direction, and head orientation have rarely been investigated together with respect to interaction effects within emotion perception. Most studies exploring emotion recognition have only considered two of these variables while the third was kept constant. However, Ganel (2011) studied the relationship between the perception of facial expression and gaze direction while at the same time varying head orientation. What he found is that under such ecologically valid conditions – when all information from head and face are present as they are in everyday social interactions – neither did gaze direction interfere with the processing of facial expression, nor did the latter alter the processing of gaze direction (Ganel, 2011).

The impact of facial masks on emotion recognition

Since the COVID-19 crisis, the mask has emerged as another influential factor with a versatile impact on facial perception and, in particular, emotion recognition. The mask impairs facial perception in quantitative and qualitative ways. Face masks impede face recognition and identification (Carragher and Hancock, 2020; Freud et al., 2020; Noyes et al., 2021) and cause a switch from a holistic to a more local, feature-based processing mode, in adults and children (Freud et al., 2020; Stajduhar et al., 2021). The impact of mask wearing on the recognition of basic emotions has by now been well researched. Most studies reported a general deterioration of emotion recognition accuracy by around 20% (Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021; Kim et al., 2022; McCrackin et al., 2022). In contrast, Calbi et al. (2021) observed only a rather negligible impairment of emotion recognition when they presented static facial expressions of anger, happiness, and neutral faces with or without a sanitary mask or a scarf. Mask wearing also had a negative impact on the confidence in one's own assessment of presented emotional facial expressions (Carbon, 2020; Pazhoohi et al., 2021). Moreover, masks reduced the perceived intensity of displayed emotions and amplified emotions that had not been displayed (Pazhoohi et al., 2021; Tsantani et al., 2022).

The extent of recognition impairment by facial masks varies among the individual emotions and seems to be context-specific. Several studies found no or only a slight impairment in emotion recognition for fear (Carbon, 2020; Kim et al., 2022; McCrackin et al., 2022), and the strongest impairment for disgust (Carbon, 2020; Noyes et al., 2021; McCrackin et al., 2022). A severe impairment was also observed for sadness (Marini et al., 2021; Kim et al., 2022), anger (Kim et al., 2022; McCrackin et al., 2022), surprise (Kim et al., 2022), fear (Noyes et al., 2021) and happiness (Carbon, 2020). However, sometimes the recognition of happiness was surprisingly well preserved (Marini et al., 2021; Kim et al., 2022; McCrackin et al., 2022). Mask wearing altered the confusion patterns among different emotions, such that several emotions were misinterpreted as neutral, and anger, disgust, and sadness were more frequently confused with each other (Carbon, 2020; Kim et al., 2022).

Aims and hypotheses

So far, the effects of masks on emotion recognition have typically been studied with frontal portraits of forward-looking faces and without consideration of interaction effects among the emotional signals and extraneous cues. To the best of our knowledge, this is the first study to examine the impact of mask wearing on integrative recognition of basic emotions while varying three social cues – facial expression, gaze direction, and head orientation. Thus, the aim of the current study is to explore how gaze direction, head orientation, and emotional facial expression interact with respect to emotion perception, and how these interactions are altered by wearing a face mask.

To address this aim, our first experiment investigated interaction effects within emotion recognition, which occur with uncovered faces. For this purpose, we presented static face stimuli from the *Radboud Faces Database* (*RaFD*) displaying five facial expressions in combination with three different angles of gaze direction and head orientation each. We recorded emotion recognition performance, perceived gaze direction, and perceived head orientation. In a second experiment, we examined the impact of mask wearing on these interaction effects by adding realistic masks to the face stimuli with all other parameters remaining unchanged.

Without mask, we expected a deterioration in emotion recognition with gaze and head deflection compared to straight gaze and frontal head, with stronger effects of head orientation. This prediction was based on the assumption that a direct gaze facilitates emotion recognition due to attention binding, as compared to an averted gaze. A frontal – compared to an averted – head should facilitate emotion recognition due to higher signaled relevance and maximum visibility of mimic signals. We also hypothesized that emotion recognition is generally impaired by mask wearing and happiness is most affected. We presumed the greatest impairment for happiness due to the unique visual saliency and high diagnostic value of the smiling mouth. Finally, we expected that the influence of gaze direction and head orientation increases when wearing a mask. We reasoned that mask wearing decreases discriminability and thereby increases ambiguity of the displayed emotions, resulting in a higher susceptibility of emotion perception to the extraneous cues of gaze direction and head orientation.

Experiment 1

Materials and methods

Design

We designed the study as a repeated-measures experiment with four within-subjects factors: *face model* (four levels: two female and two male models), *facial expression* (five levels: anger, fear, happiness, neutral, and sadness), *gaze direction* (three levels: left, centered, and right), and *head orientation* (three levels: left, frontal, and right). All factors were fully crossed, resulting in a total of 180 stimuli. We implemented this design as an online experiment on the online platform *SoSci Survey*[1]. Each subject judged all 180 factorial combinations in different random orders. The main dependent variable was emotion recognition performance. Perceived gaze direction, head orientation, valence, and arousal were gathered as control variables to check the manipulation of the independent variables and to assess the quality of our study. This was particularly important as we had implemented an online experiment with limited controllability of the experimental setting. The assessment of perceived gaze direction and head orientation enabled to verify whether participants picked up the actual changes of gaze direction and head orientation. These measures further provided a baseline to later clarify (Exp. 2) whether mask-induced changes are mainly mediated by changes in emotion perception or by changes in the perception of gaze direction and head orientation. Valence and arousal were recorded to make sure that the five facial expressions evoked distinguishable emotional responses in our subjects. Furthermore, the recording of valence and arousal also allowed to ascertain whether there are major differences in the display of the facial expressions between the models.

Participants

Fifty-three subjects participated voluntarily in this online study. Ten subjects (19%) chose to abort the experiment before completion, and four subjects were eliminated because they had failed to follow the instructions. Given the length of the experiment, we consider the drop-out rate to be quite acceptable for an online experiment. The experiment took 70 min even when carrying out the task promptly and without breaks. The resulting sample comprised 39 adults (32 female and 7 male) aged from 19 to 60 years (M = 25.67 years, SD = 7.40 years), 87% of which were students. All reported normal or corrected-to-normal vision. They were recruited by means of university mailing lists and different social media platforms. Psychology students of the University of Mainz received partial course credit for participation. In accordance with the Declaration of Helsinki, all subjects gave written informed consent and were debriefed after the experiment. The study was conducted in line with the ethical standards of the local ethics board of the Psychological Institute of Mainz University. Since voluntary participation on a fully informed basis and anonymity were assured, and there was no risk for physical stress or disadvantages due to group assignment, the research fell under the blanket approval of the ethics board.

1 https://www.soscisurvey.de

10.3389/fnins.2022.937939

Material

All face stimuli were obtained from the *Radboud Faces Database* (*RaFD*) (Langner et al., 2010). We used faces from four different Caucasian adults (two female: model 1, model 14, two male: model 20, model 23), each displaying five facial expressions (anger, fear, happiness, neutral, and sadness), paired with three different angles of gaze directions (left: −13°, centered: 0°, and right: 13°), and viewed from three different perspectives, which corresponded to three different angles of head orientation (left: −45°, frontal: 0°, and right: 45°). **Figure 1** illustrates the interdependency between gaze direction and head orientation. Note that the pictures were taken simultaneously with a synchronized camera-array around the model, such that the exact same facial expression was photographed from all viewing angles (i.e., head orientations). This resulted in 180 face stimuli in total (4 models × 5 facial expressions × 3 gaze directions × 3 head orientations). The selection of the four models was based on the clarity and authenticity of the displayed facial expressions. All facial expressions from the *RaFD* were based on prototypes from the *Facial Action Coding System* (FACS; Ekman et al., 2002) and were monitored by FACS specialists during the photo shoot (Langner et al., 2010). Note that all four models had their mouth open and showed teeth when displaying happiness and, to a small extent, when displaying fear, but had their mouth closed when displaying neutral, anger and sadness. The original photographs were edited with *Photoscape*. Each image was scaled down to a resolution of 681 pixels × 570 pixels and cropped to remove background and upper body. Example stimuli are illustrated in **Figure 2**.

Procedure

Data collection took place between October 04 and November 30, 2020. Participants completed the online experiment by accessing a link, which they had received in advance. They were instructed to use a computer or a laptop, and all of them did so, with the exception of one subject who reported to have used a tablet. Before the experimental section started, they gave informed consent. During the experimental section, they were asked to assess facial stimuli as quickly and intuitively as possible in terms of (a) perceived gaze direction, (b) perceived head orientation, (c) displayed facial expression, and (d) valence and arousal. The time to respond was not limited. All ratings were made by click (mouse or touch). Each face stimulus was presented in color against a white background, centered in the middle of a single page, with the assessment tasks arranged around it. The two scales assessing gaze direction (left) and head orientation (right) were placed at the top, an emotion categorization task was placed at the bottom left, and the two scales assessing valence and arousal were placed at the bottom right (for an example page see **Supplementary Material**).

Prior to the 180 experimental trials, all subjects completed the same training trial with one face stimulus, which was not part of the experimental stimulus set. The categorization of the displayed emotion was the main task and focus of interest. The remaining dependent variables primarily served as a manipulation check and to assess the quality of our online study. (a) and (b): Participants indicated perceived gaze direction and head orientation by means of two svg-graphics, which were internally created with the help of *Inkscape* (see **Figure 3**). The graphics each showed a person from a bird's eye view surrounded by evenly spaced black dots arranged on a semicircle, each dot comprising 5° and the center of each dot marking a 5° step from 0° to 180°. A red dot indicated the position of the observer. Subjects had to select the circle that most closely matched the direction in which the displayed face was looking or pointing his or her head, respectively. (c): The displayed facial expressions were categorized by means of a single-choice task with eight response options. Participants indicated the emotional expression they believed to recognize in the face by selecting the most appropriate emotional label among the following eight options: *happiness*, *anger*, *sadness*, *contempt*, *disgust*, *neutral*, *fear,* and *surprise*. Three of these options represented distractors (*contempt*, *disgust*, and *surprise*). The response options were always presented in the same order to avoid errors that might have arisen when randomly switching their order, which would have introduced an additional processing demand. (d): Valence and arousal were recorded using visual analog scales ranging from *negative* to *positive* (valence), and from *calm* to *aroused* (arousal), respectively. Face stimuli and scales all appeared at the same time and remained on screen until all ratings had been completed and the subject navigated to the next page. Following the experimental trials, participants were asked to provide demographic data, and to answer several questions regarding personality traits as well as behaviors and experiences in the context of non-verbal communication (for the exact questions and answers see **Supplementary Material**). Finally, participants were debriefed and had the opportunity to receive partial credit for their participation. In total, the experiment lasted about 70 min.

Results

We first report the results for emotion recognition, then we give a short overview of the control variables.

To investigate the influence of the displayed facial expression, gaze direction, and head orientation on emotion recognition performance, we conducted a 5 × 3 × 3 repeated-measures analysis of variance (rmANOVA; univariate approach) with emotion (anger, fear, happiness, neutral, and sadness), gaze direction (left, centered, and right), and head orientation (left, frontal, and right) as within-subject factors. The rate of correctly recognized emotional facial expressions served as the dependent variable. These values were aggregated across the four models. Subsequently, we calculated four further rmANOVAs with the

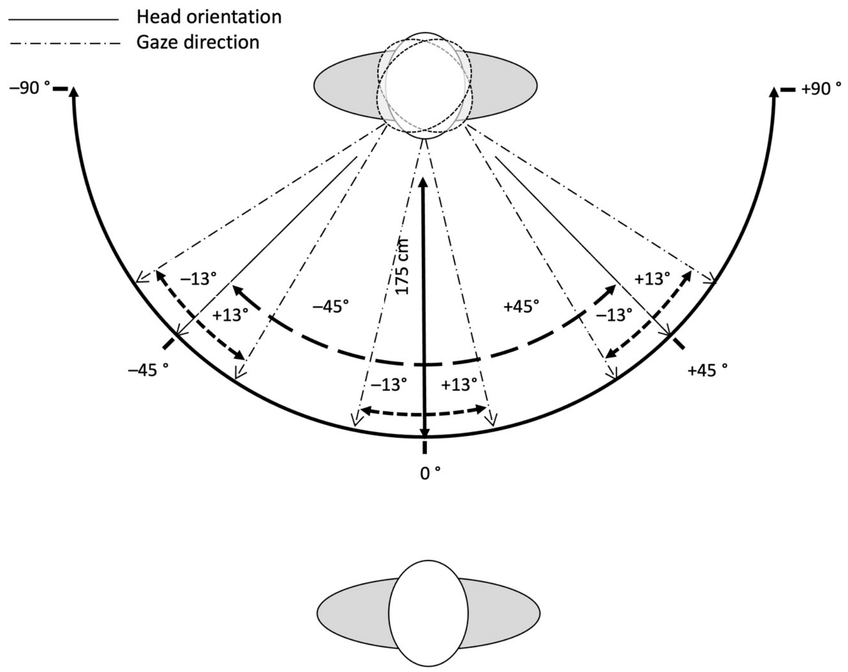

FIGURE 1
Schematic illustration of the variation of gaze direction and head orientation. Note that the models changed their gaze direction and facial expression. Head orientation was achieved with synchronized cameras at 0°, 45°, and −45° relative to frontal view.

same factorial design for the additional dependent measures judged gaze direction, head orientation, valence, and arousal.

All tests were performed at a significance level of $\alpha = 0.05$. We performed power analyses using G*Power (Faul et al., 2007). In all subsequent rmANOVAs, a sample size of 39 was sufficient to achieve a power of over 80% at an alpha of 5% for each reported effect. Where indicated, we used the Greenhouse-Geisser correction for the degrees of freedom (correction factor ε; this correction was applied to all subsequent ANOVAs). As a *post hoc* analysis, we conducted univariate rmANOVAs with the same factorial design separately for each emotion or pairwise comparisons, which were corrected according to Hochberg (1988) to account for multiple testing. Prior to conducting pairwise comparisons, the differences between the paired values were routinely analyzed for normality of distribution by using Shapiro–Wilk tests (see **Supplementary Material**). In some cases, the normality assumption was violated. For reasons of consistency, however, Wilcoxon signed-rank tests were then calculated for all pairwise comparisons. For all corresponding data sets, additionally to means and SDs, medians (Mdns) and 95% confidence intervals (CIs) are reported.

Emotion recognition

Basic emotion recognition

Overall, participants recognized emotional facial expressions from unmasked faces with a recognition rate of 85.1% (*SD* = 8.3%), which was clearly above the chance level of 12.5%. Recognition performance, however, differed depending on the emotion presented, with a clear recognition advantage for happiness and a clear recognition disadvantage for fear (see **Figure 4**; anger: *M* = 93.4%, *SD* = 10.8%, fear: *M* = 63.5%, *SD* = 24.1%, happiness: *M* = 99.4%, *SD* = 1.3%, neutral: *M* = 81.8%, *SD* = 18.4%, sadness: *M* = 87.3%, *SD* = 14.0%). Overall, we found the following rank order of emotion recognition performance: *happiness* > *anger* > *sadness* > *neutral* > *fear* (see **Figure 4**).

In line with these observations, the main effect of emotion was significant, $F(4,152) = 33.38$, $p < 0.001$, $\eta_p^2 = 0.468$, $\varepsilon = 0.68$. According to the *post hoc* tests, all emotions except for neutral and sadness, $z = -1.21$, $p_{corr} = 0.227$, $r = 0.19$, differed significantly from each other in the direction of the rank order shown in **Figure 4**, all $|z| \geq 2.70$, $p_{corr} \leq 0.014$, $r \geq 0.43$ (for more details see **Supplementary Material**).

Emotion recognition performance also varied depending on the idiosyncrasies of the models. For instance, fear was particularly poorly recognized in the female model 1 and in the male model 20.

Integrative emotion recognition

The effects of gaze direction and head orientation were less obvious. Overall, emotion recognition performance with averted gaze or head was almost as good as with centered gaze and frontally aligned head, with the exception of a small drop in recognition performance for leftward gaze (see **Figures 5A,C**).

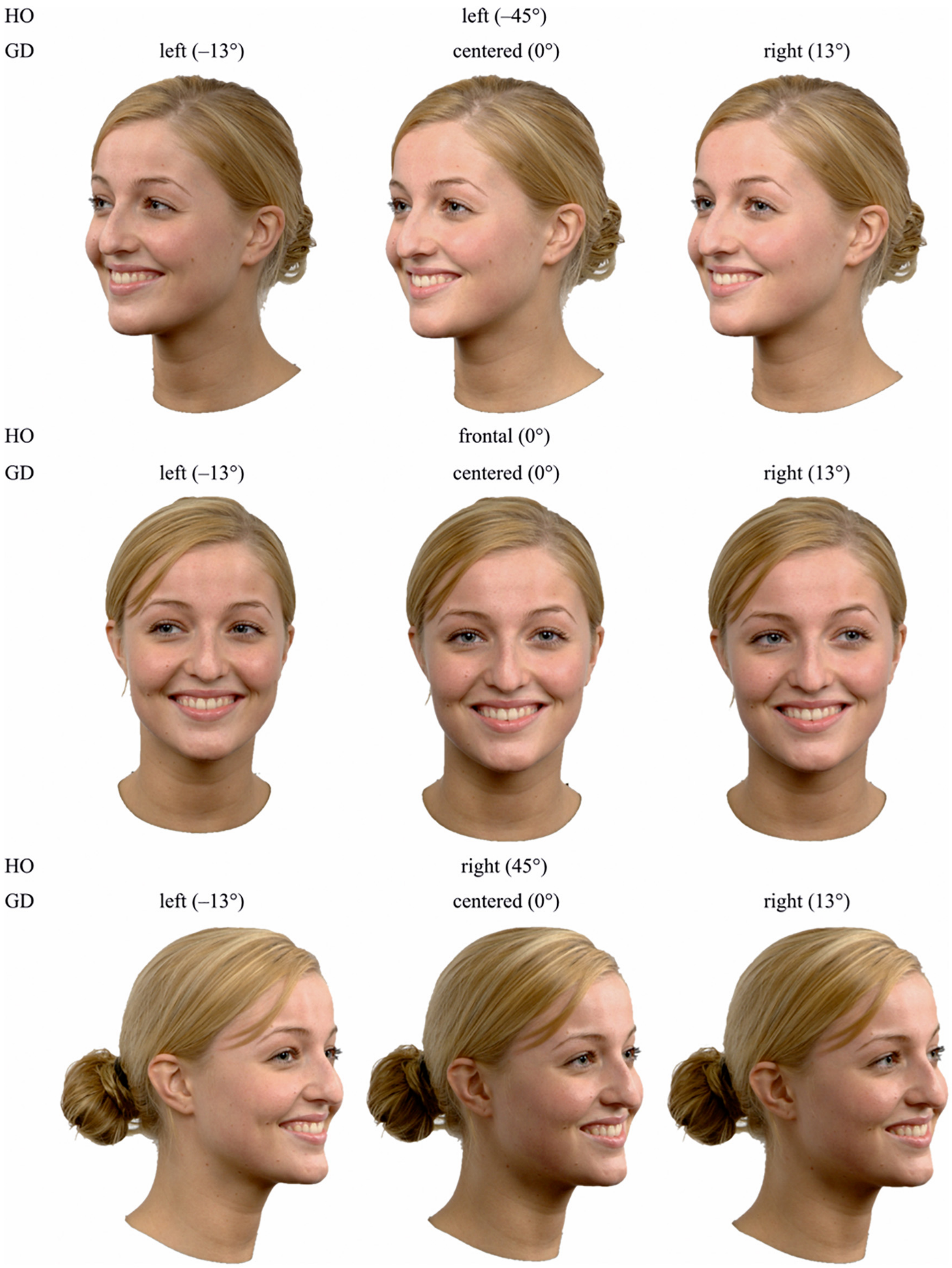

FIGURE 2
Example stimuli for uncovered faces, showing all nine possible combinations of gaze direction and head orientation for model 1 and the facial expression happiness. HO, head orientation; GD, gaze direction.

The rmANOVA showed a significant main effect of gaze direction, $F(2,76) = 10.75$, $p < 0.001$, $\eta_p^2 = 0.220$. According to the *post hoc* tests, emotion recognition was significantly reduced with left gaze than with centered gaze, $z = -3.45$, $p_{corr} = 0.002$, $r = 0.55$, as well as with right gaze, $z = -3.32$, $p_{corr} = 0.002$, $r = 0.53$; right gaze and centered gaze did not differ

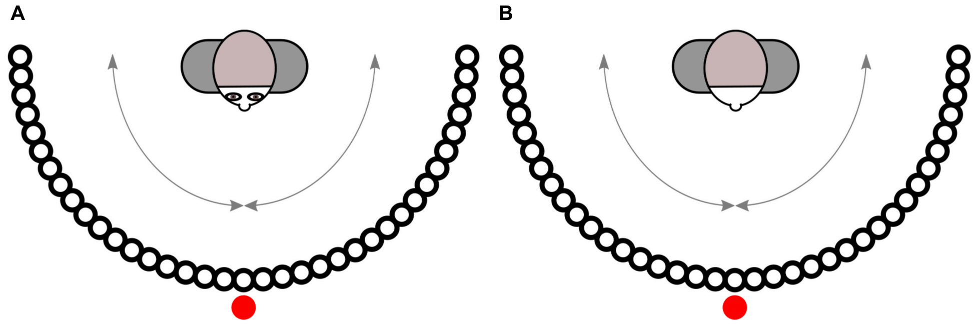

FIGURE 3
Svg-graphics for the assessment of gaze direction **(A)** and head orientation **(B)**.

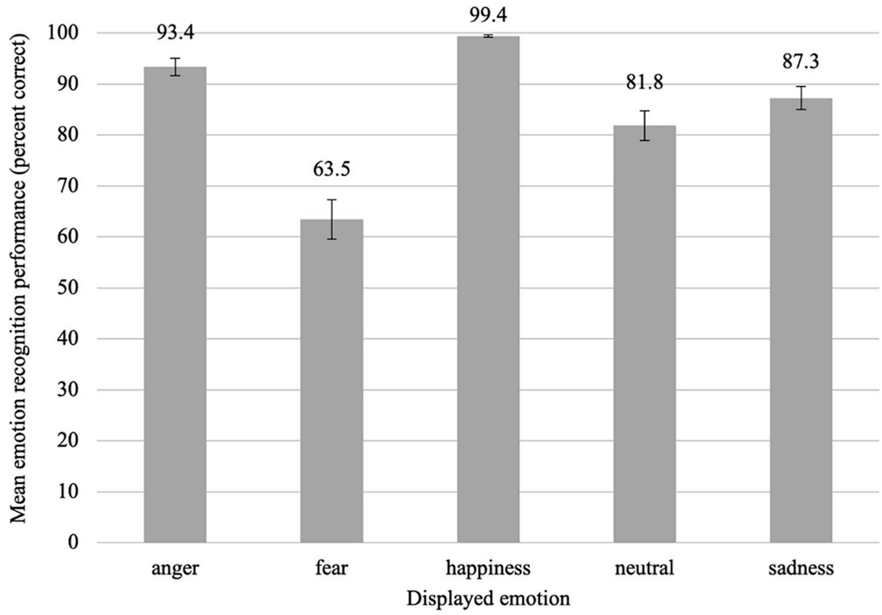

FIGURE 4
Mean emotion recognition performance in percent correct for uncovered faces as a function of the displayed emotion, averaged across all gaze directions and head orientations. Error bars indicate the standard error of the mean (SEM) of the 39 individual data points in each condition.

significantly from each other, $z = -1.06$, $p_{corr} = 0.290$, $r = 0.17$. The main effect of head orientation was clearly not significant, $F(2,76) = 0.07$, $p = 0.935$, $\eta_p^2 = 0.002$.

As can be seen in **Figures 5B,D**, the effects of gaze direction and head orientation varied in size and direction depending on the displayed emotion. Neutral, sadness, and fear appeared to be most affected. Note that, averaged across all gaze directions, anger and neutral tended to be recognized even better with averted head than with frontal head, and, averaged across all head orientations, fear tended to be recognized even better with averted gaze than with centered gaze.

In the rmANOVA, the emotion × gaze direction interaction was significant, $F(8,304) = 7.81$, $p < 0.001$, $\eta_p^2 = 0.170$, $\varepsilon = 0.58$, while the emotion × head orientation interaction was not significant, $F(8,304) = 1.67$, $p = 0.139$, $\eta_p^2 = 0.042$, $\varepsilon = 0.66$. To examine the emotion × gaze direction interaction in more detail, we calculated separate rmANOVAs for each emotion. These *post hoc* tests showed that gaze direction significantly affected the recognition performance for the three most poorly recognized emotions: fear, $F(2,76) = 5.88$, $p = 0.004$, $\eta_p^2 = 0.134$, neutral, $F(2,76) = 16.29$, $p < 0.001$, $\eta_p^2 = 0.300$, and sadness, $F(2,76) = 5.61$, $p = 0.005$, $\eta_p^2 = 0.129$, with neutral being the most affected. Happiness, $F(2,76) = 0.14$, $p = 0.870$, $\eta_p^2 = 0.004$, and anger, $F(2,76) = 1.32$, $p = 0.274$, $\eta_p^2 = 0.033$, were not significantly affected. The strong effect for the neutral faces can possibly be attributed to the fact that neutral as non-emotional facial expression is rarely 'perfect' in the sense of a complete absence of mimic signals, but rather to a greater or lesser extent, depending

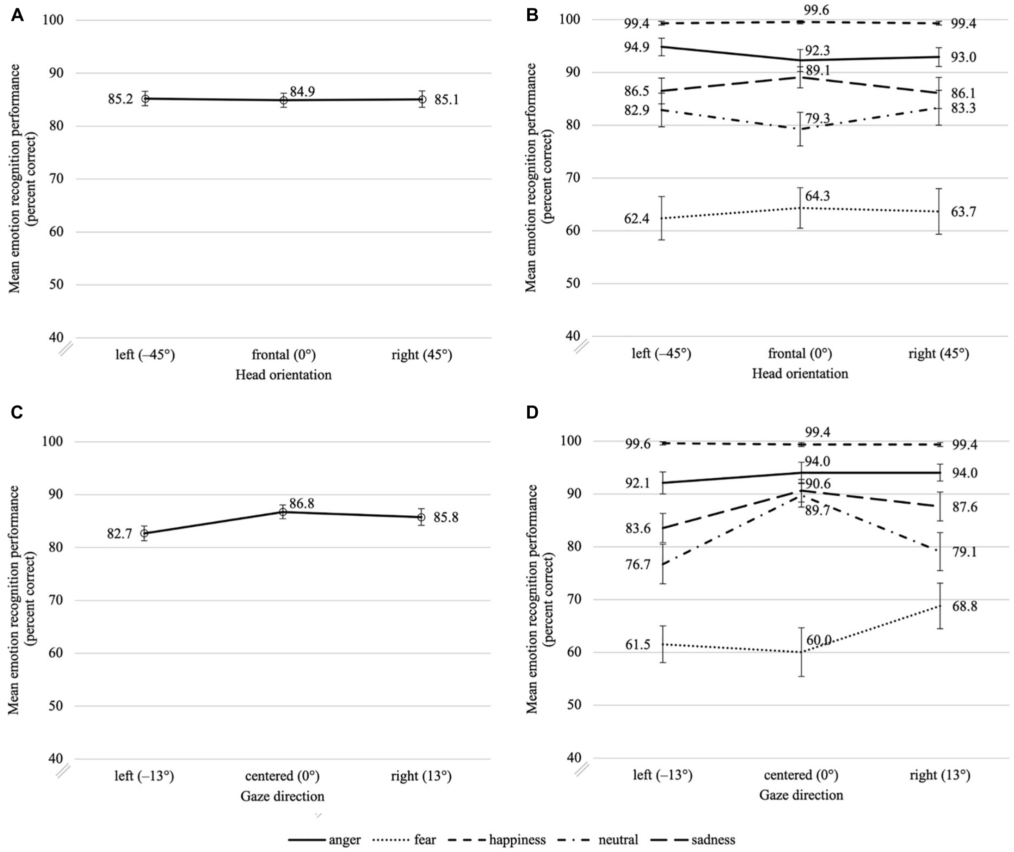

FIGURE 5
Mean emotion recognition performance in percent correct for uncovered faces as a function of head orientation (top row, **A,B**) and gaze direction (bottom row, **C,D**), aggregated across all facial expressions (left column, **A,C**) and additionally as a function of the five different facial expressions (right column, **B,D**). Error bars indicate the standard error of the mean (SEM) of the 39 individual data points in each condition.

on the model, contains emotion-specific mimic signals. This might increase ambiguity, which is tried to be solved by seeking further information from other social dimensions. In sum, these results suggest that emotion recognition remained at comparable levels across the manipulation of gaze direction and head orientation with some variation due to changes in gaze direction in performance for all emotions but happiness and anger. Thus, the effect of gaze direction on emotion recognition appears to be modulated by the degree of discriminability of the displayed emotion, with more ambiguous emotions being more likely to be influenced by gaze direction. *Post hoc* tests showed that fear was detected better with averted gaze than with centered gaze, whereas neutral and sadness were recognized better with centered gaze than with averted gaze, whereby the effect of gaze direction was symmetrical only for neutral (see **Table 1**).

Control variables

Since we did not observe any surprising significant phenomena that were relevant for our research question, the results of the analysis of perceived gaze direction and head orientation are reported only briefly. Both gaze direction and head orientation were correctly interpreted by the participants according to the instructions and estimated quite well overall. For perceived gaze direction, we found a slight leftward bias, for perceived head orientation, we observed a slight rightward bias. Since both biases appeared across models, we assume that the position of the assessment scales (left: gaze direction and right: head orientation) had caused these distortions.

In line with our expectations and previous research (Hecht et al., 2021), but surprisingly limited to the frontal head orientation, we found a repulsion effect of head orientation on perceived gaze direction as well as an attraction effect of gaze direction on perceived head orientation (the data can be found in the **Supplementary Material**). Perceived gaze was misestimated to diverge more from the centered head orientation than was actually the case (repulsion effect). At the same time a given gaze direction pulled the judged head orientation toward the gaze (attraction effect). However, for averted head orientation, the effects of gaze direction and head

TABLE 1 Experiment 1: Results of the Wilcoxon signed-rank tests for correct emotion recognition (percentages given as decimals) (N = 39).

Comparison	$\bar{\Delta}$	$Mdn\ (x_1 - x_2)$	95% CI	z	p_{corr}	r
Fear						
Gaze direction						
Left – centered	0.01	0.00	[−0.04, 0.07]	−0.45	0.654	0.07
Right – centered	0.09	0.00	[0.03, 0.14]	−2.97	0.009	0.48
Left – right	−0.07	−0.08	[−0.13, −0.02]	−2.46	0.028	0.39
Neutral						
Gaze direction						
Left – centered	−0.13	−0.08	[−0.19, −0.07]	−3.86	<0.001	0.62
Right – centered	−0.11	−0.08	[−0.16, −0.06]	−3.61	<0.001	0.58
Left – right	−0.02	0.00	[−0.06, 0.02]	−1.06	0.288	0.17
Sadness						
Gaze direction						
Left – centered	−0.07	0.00	[−0.12, −0.02]	−2.84	0.015	0.45
Right – centered	−0.03	0.00	[−0.07, 0.01]	−1.65	0.099	0.26
Left – right	−0.04	0.00	[−0.08, 0.00]	−2.14	0.064	0.34

Pearson's r is reported as a measure of effect size.

orientation changed or did not occur at all: For perceived gaze direction the repulsion effect changed into an attraction effect, but for the perceived head orientation the attraction effect was no longer detectable under such conditions. Those interaction patterns were basically the same for all five facial expressions.

Concerning perceived valence and arousal, the facial expressions were perceived as differently pleasant and arousing according to a constant rank order from high to low across all gaze directions and head orientations (valence: *happiness* > *neutral* > *fear* > *sadness* > *anger*; arousal: *fear* > *anger* > *happiness* > *sadness* > *neutral*).

Overall, the data of the control variables indicate that our online experiment, despite its inherent limitations, yielded estimates of average head orientation and average gaze direction at the same accuracy levels (within a few degrees) as those obtained previously in related laboratory experiments (Hecht et al., 2021).

Experiment 2

Materials and methods

Design

This experiment was a perfect replication of Exp. 1 with the only difference that the models wore a facial mask. The latter was photoshopped into the original photographs. We used the same repeated measures design as in the first experiment, using the same factors and dependent variables as before. Thus, in the combined analysis, the between-factor of mask emerged (Exp. 1: without mask, Exp. 2: with mask) leading to a mixed design with facial expression, gaze direction, and head orientation as within-subject factors, and with *mask* as between-subject factor.

Participants

A total of 71 subjects participated in this online study. 14 subjects (20%) dropped out early and seven subjects were eliminated because they failed to follow the instructions. Another five subjects were excluded because they had already participated in the first experiment. Again, we consider the drop-out rate to be quite acceptable for an online experiment lasting more than 1 h. This resulted in a final sample size of 45 adults (31 female and 14 male) aged from 18 to 53 years (M = 26.67 years, SD = 7.95 years), 93% of which were students. All indicated normal or corrected-to-normal vision. They were briefed and debriefed as before. Recruitment procedure and compensation were identical to Exp. 1.

Material

The face stimuli were the same stimuli as in the first experiment, except that a face mask was superimposed on each face using *GIMP* (*GNU Image Manipulation Program*). For this purpose, we photographed a surgical face mask from angles corresponding to the displayed head orientations of the face stimuli (−45°, 0°, and 45°). Then, the photographs were cropped to remove background and original ear loops (see **Supplementary Material**), graphically adjusted to the individual faces, and complemented with matching ear loops. The image height of the stimuli remained unchanged while the image width was extended to 400 pixels. Example stimuli are illustrated in **Figure 6**.

FIGURE 6
Example stimuli for masked faces, showing all nine possible combinations of gaze direction and head orientation for model 20 and the facial expression anger. HO, head orientation; GD, gaze direction.

Procedure

The online experiment was identical to the first experiment, except that the mask had been added to the face stimuli, and participants were additionally asked whether they had already participated in the first experiment. Accordingly, the experiment also lasted about 70 min. All participants used a computer or laptop as instructed, except for one, who used a smartphone. Data collection took place between March 18 and May 31, 2021.

Results

We first report the results for emotion recognition, then we give a short overview of the results for the control variables.

In order to investigate the influence of mask wearing on participants' emotion recognition performance as well as on the interactions between displayed facial expression, gaze direction, and head orientation within emotion recognition, we calculated a 2 (mask) × 5 (emotion) × 3 (gaze direction) × 3 (head orientation) mixed ANCOVA using the same within-subjects factors as before, and adding the between-subjects factor mask (Exp. 1: without mask and Exp. 2: with mask) as well as the covariate of participant gender to account for slightly different gender distributions in Exp. 1 (~82% females) and Exp. 2 (~69% females). To further investigate mask interactions, we conducted a rmANOVA for masked stimuli in an analogous manner to the rmANOVA in Exp. 1 to be able to directly compare the effects for uncovered and masked stimuli. For each control variable reported below, we conducted a mixed ANCOVA using the same factorial design as for emotion recognition performance.

Emotion recognition

Basic emotion recognition

With mask, the overall emotion recognition rate dropped to 75.5% (*SD* = 8.7%), amounting to a deterioration of almost 10%. **Figure 7** illustrates the emotion recognition performance for masked faces compared to uncovered faces as a function of the displayed emotion. It is important to note that the recognition rate for all emotions remained clearly above the chance level of 12.5%. Taking a closer look at **Figure 7**, it becomes evident that the mask deteriorated recognition performance for all facial expressions except for neutral, for which it even slightly improved it. Obviously, the reduction of visible mimic signals is not necessarily always adverse for emotion recognition but can also sometimes protect against overinterpretation. It appears very plausible that in the case of a neutral facial expression, which is characterized by the absence of mimic signals, a reduction of visible facial regions can have a beneficial effect. What is surprising, however, is the very strong deterioration for sadness, with losses of about 30%, as well as a strong deterioration for anger, with losses of about 15%. This changed the rank order of emotion recognition performance from *happiness* > *anger* > *sadness* > *neutral* > *fear* (Exp. 1) to *happiness* > *neutral* > *anger* > *fear* > *sadness* (Exp. 2). In line with these observations, the mixed ANCOVA revealed a significant main effect of mask, $F(1,81) = 25.35$, $p < 0.001$, $\eta_p^2 = 0.238$, and a significant mask × emotion interaction, $F(4,324) = 18.08$, $p < 0.001$, $\eta_p^2 = 0.182$, $\varepsilon = 0.82$.

The rmANOVA for masked stimuli showed that the effect of the displayed emotion on recognition performance, $F(4,176) = 62.85$, $p < 0.001$, η_p^2 0.588, $\varepsilon = 0.74$, was somewhat more pronounced than for uncovered faces ($\eta_p^2 = 0.468$). *Post hoc* tests showed that, with mask, all presented emotions except for fear and sadness, $z = -0.77$, $p_{corr} = 0.444$, $r = 0.11$, differed significantly from each other in recognition performance, all $|z| \geq 2.59$, $p_{corr} \leq 0.020$, $r \geq 0.39$ (for more details see **Supplementary Material**).

Thus, wearing a mask led to a reduction in overall emotion recognition performance, notwithstanding some variation in performance decrement depending on the displayed emotion and the idiosyncrasies of the models, with emotion and model each exerting a greater influence compared to unmasked faces. For instance, we found particularly poor recognition of sadness in the female model 14.

Integrative emotion recognition

The effect of head orientation on emotion recognition remained weak, but the mask had reversed the direction of this effect for all emotions except neutral, and now all emotions except anger tended to be better recognized with averted head as compared to frontal head (see **Figures 8A,B**).

In the mixed ANCOVA, the mask × head orientation interaction, $F(2,162) = 1.34$, $p = 0.264$, $\eta_p^2 = 0.016$, and the mask × emotion × head orientation three-way interaction were not significant, $F(8,648) = 1.45$, $p = 0.192$, $\eta_p^2 = 0.018$, $\varepsilon = 0.76$, which indicates that mask wearing did not significantly change the effect of head orientation on emotion recognition performance. Note, however, that in the rmANOVA for masked stimuli both the main effect of head orientation, $F(2,88) = 3.14$, $p = 0.048$, $\eta_p^2 = 0.067$, and the emotion × head orientation interaction, $F(8,352) = 2.72$, $p = 0.016$, $\eta_p^2 = 0.058$, $\varepsilon = 0.71$, were significant, though small. For the main effect of head orientation, the *post hoc* tests showed no significant differences between the individual head orientations, all $|z| \leq 2.06$, $p_{corr} \geq 0.117$, $r \leq 0.31$ (for more details see **Supplementary Material**). The separate *post hoc* rmANOVAs for the individual emotions revealed that, with mask, head orientation had a significant effect on recognition performance for anger, $F(2,88) = 4.18$, $p = 0.019$, $\eta_p^2 = 0.087$, happiness, $F(2,88) = 3.22$, $p = 0.045$, $\eta_p^2 = 0.068$, and neutral, $F(2,88) = 7.87$, $p = 0.002$, $\eta_p^2 = 0.152$, $\varepsilon = 0.79$. Fear, $F(2,88) = 0.26$, $p = 0.774$, $\eta_p^2 = 0.006$, and sadness, $F(2,88) = 0.68$, $p = 0.508$, $\eta_p^2 = 0.015$, were not significantly affected. Going further into detail, *post hoc* tests showed that happiness and neutral were better recognized with averted head orientation, while there were no significant differences between the head orientations for anger (see **Table 2**). The effect of gaze direction had clearly gained influence, especially

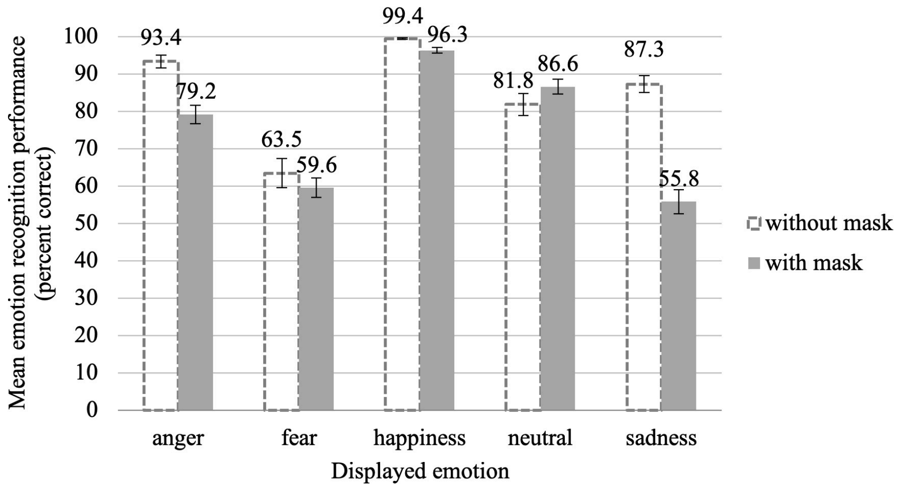

FIGURE 7
Mean emotion recognition performance in percent correct for uncovered faces (dashed bars; Exp. 1) and masked faces (filled bars; Exp. 2) as a function of the displayed emotion, averaged across all gaze directions and head orientations. Error bars indicate the standard error of the mean (SEM) of the 39 and 45 individual data points per displayed emotion, respectively.

for the emotions that were most poorly recognized with mask: sadness, fear, and anger (see **Figures 8C,D**). Furthermore, with mask, the rank-order changed depending on gaze direction, whereas, without mask, it had remained constant across all head orientations and gaze directions. In line with this, in the mixed ANCOVA the mask × gaze direction interaction just missed significance, $F(2,162) = 3.02$, $p = 0.052$, $\eta_p^2 = 0.036$, in combination with a clearly significant mask × emotion × gaze direction three-way interaction, $F(8,648) = 6.82$, $p < 0.001$, $\eta_p^2 = 0.078$, $\varepsilon = 0.72$. This indicates that the effect of gaze direction on emotion recognition performance changed as a function of both mask wearing and displayed emotion. In the rmANOVA for masked stimuli, the main effect of gaze direction, $F(2,88) = 29.67$, $p < 0.001$, $\eta_p^2 = 0.403$, was more prominent than for the uncovered faces ($\eta_p^2 = 0.220$). Comparable with the results of Exp. 1, emotion recognition was significantly reduced with left gaze than with centered gaze, $z = -4.80$, $p_{corr} < 0.001$, $r = 0.72$, as well as with right gaze, $z = -5.45$, $p_{corr} < 0.001$, $r = 0.81$, and right gaze and centered gaze did not differ significantly from each other, $z = -0.25$, $p_{corr} = 0.803$, $r = 0.04$. The rmANOVA also showed a significant emotion × gaze direction interaction, $F(8,352) = 24.12$, $p < 0.001$, $\eta_p^2 = 0.354$, $\varepsilon = 0.66$, which was also more pronounced than for the uncovered stimuli ($\eta_p^2 = 0.170$). The *post hoc* rmANOVAs run separately for the individual emotions showed that, in addition to the effects already found in Exp. 1 for fear, $F(2,88) = 31.82$, $p < 0.001$, $\eta_p^2 = 0.420$, $\varepsilon = 0.85$, sadness, $F(2,88) = 22.32$, $p < 0.001$, $\eta_p^2 = 0.337$, and neutral, $F(2,88) = 21.54$, $p < 0.001$, $\eta_p^2 = 0.329$, $\varepsilon = 0.81$, gaze direction now also had a significant effect on the recognition performance for anger, $F(2,88) = 29.74$, $p < 0.001$, $\eta_p^2 = 0.403$, and, thus, now for all emotions except happiness, $F(2,88) = 2.76$, $p = 0.069$, $\eta_p^2 = 0.059$. Note that this pattern is compatible with the assumption that the influence of gaze direction increases with rising uncertainty. Thus, the deteriorating effect of mask wearing on the recognition performance for anger could explain why, with mask, the effect of gaze direction had also reached significance for this emotion. According to the *post hoc* tests, only fear was recognized better with averted gaze, while anger, neutral, and sadness were better recognized with centered gaze, whereby the effect of gaze direction was now symmetrical for all emotions except anger (see **Table 3**).

Control variables

There were no significant changes in perceived gaze direction or head orientation due to wearing a mask. With regard to emotion perception, this suggests that the observed changes in interaction effects for masked faces are mediated by changes in emotion perception and are not due to a shift in the perception of gaze direction and head orientation.

Overall, face stimuli with mask were perceived as more pleasant and more arousing than those without mask. Perceived valence increased for all emotions except happiness, for which it slightly decreased. The mask increased perceived arousal for all presented emotions except for anger, there it decreased arousal. The rank orders for both perceived valence and arousal remained basically unchanged by the mask.

Discussion

Emotional facial expressions are basically defined and, in most cases, studied based on frontally aligned faces with straight gaze. However, in everyday social interactions both head

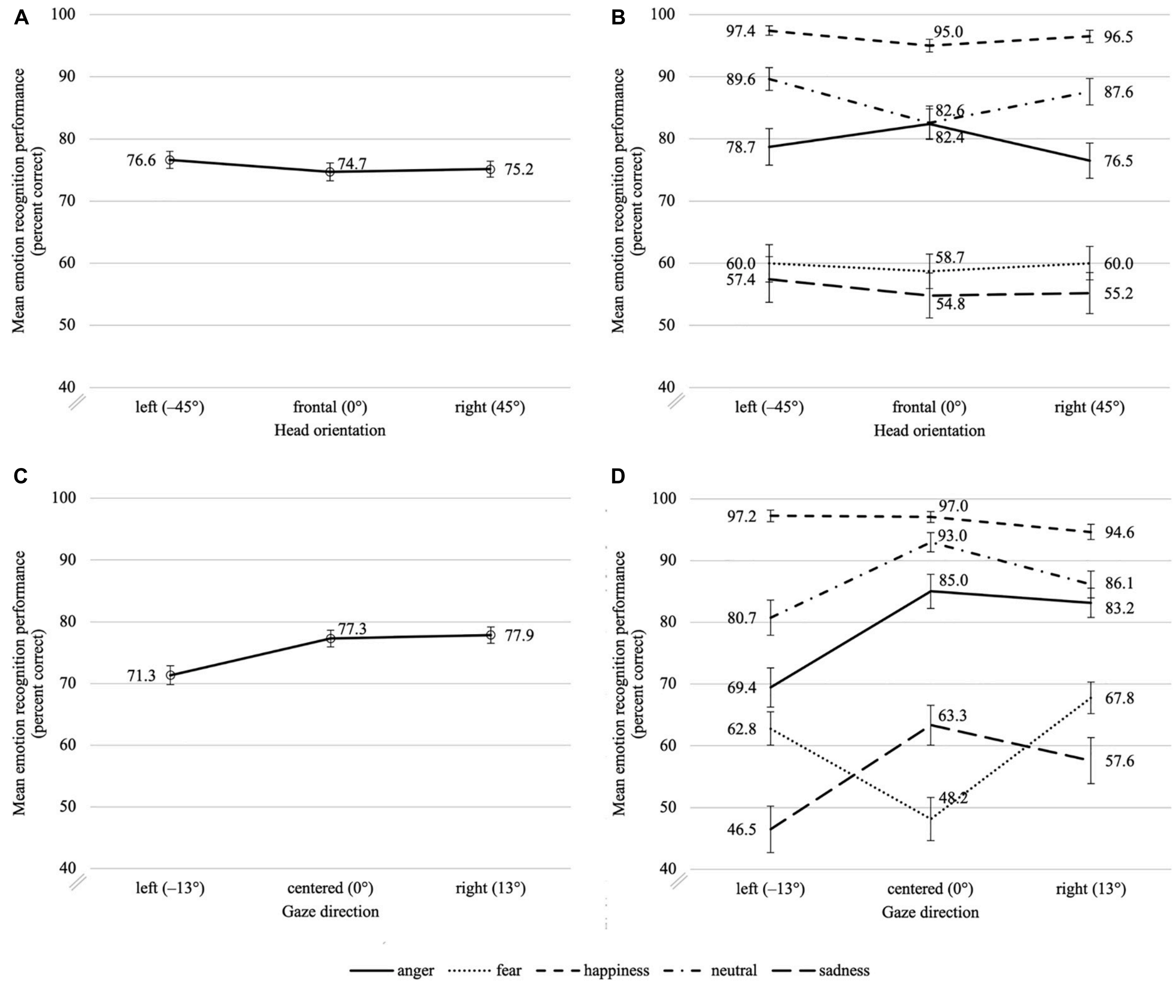

FIGURE 8
Mean emotion recognition performance in percent correct for masked faces as a function of head orientation (top row, **A,B**) and gaze direction (bottom row, **C,D**), aggregated across all facial expressions (left column, **A,C**) and additionally as a function of the five different facial expressions (right column, **B,D**). Error bars indicate the standard error of the mean (SEM) of the 39 and 45 individual data points in each condition, respectively.

orientation and gaze direction vary considerably. Turning the head sideways interrupts face symmetry and alters the visible information from facial cues such as eyebrows, eyes, nose, and mouth. Depending on their shape, size, and configuration, some features are more affected by self-occlusion than others. Averting the gaze, on the other side, also interrupts face symmetry and changes various characteristics of the eyes such as iris-eccentricity and the visible part of the sclera. Mask wearing further reduces visibility of facial features, which may remove important remaining cues in the averted face. The impact of facial masks had thus far been investigated mainly using frontally aligned faces with straight gaze. The aim of our study was to evaluate the impact of face masks on integrative emotion recognition with varying gaze direction and head orientation.

In our first experiment, we have examined interaction effects between facial expression and the extraneous cues gaze direction and head orientation that come into play during emotion recognition with uncovered faces. In the second experiment, we have then investigated how these interaction effects are altered by wearing a face mask. The findings from Exp. 1 thereby offer insight into effects of naturalistic variation of cue visibility and saliency due to head and gaze deflection on emotion recognition of uncovered faces. The results from Exp. 2 shed light on the additional effects of mask-induced occlusion of facial cues. Thus, the second experiment also addresses the interaction between two types of cue reduction: altered cue visibility of the whole face and complete absence of cues of the lower face.

With respect to emotion recognition under non-masked conditions (Exp. 1), we found an overall accuracy rate of around 85%, which is comparable to that of 82% found in the validation study of the *RaFD* (Langner et al., 2010). It should be noted, however, that for the latter only images

TABLE 2 Experiment 2: Results of the Wilcoxon signed-rank tests for correct emotion recognition (percentages given as decimals) (N = 45).

Comparison	$\bar{\Delta}$	$Mdn\ (x_1 - x_2)$	95% CI	z	p_{corr}	r
Anger						
Head orientation						
Left – frontal	−0.04	0.00	[−0.07, 0.00]	−1.78	0.150	0.27
Right – frontal	−0.06	−0.08	[−0.11, −0.01]	−2.36	0.054	0.35
Left – right	0.02	0.08	[−0.02, 0.06]	−1.14	0.256	0.17
Happiness						
Head orientation						
Left – frontal	0.02	0.00	[0.01, 0.04]	−2.60	0.027	0.39
Right – frontal	0.01	0.00	[−0.01, 0.04]	−1.31	0.308	0.20
Left – right	0.01	0.00	[−0.01, 0.03]	−1.02	0.308	0.15
Neutral						
Head orientation						
Left – frontal	0.07	0.00	[0.03, 0.11]	−3.52	<0.001	0.52
Right – frontal	0.05	0.00	[0.01, 0.09]	−2.10	0.072	0.31
Left – right	0.02	0.00	[−0.01, 0.05]	−1.41	0.160	0.21

Pearson's r is reported as a measure of effect size.

TABLE 3 Experiment 2: Results of the Wilcoxon signed-rank tests for correct emotion recognition (percentages given as decimals) (N = 45).

Comparison	$\bar{\Delta}$	$Mdn\ (x_1 - x_2)$	95% CI	z	p_{corr}	r
Anger						
Gaze direction						
Left – centered	−0.16	−0.17	[−0.20, −0.11]	−4.96	<0.001	0.74
Right – centered	−0.02	0.00	[−0.06, 0.02]	−0.91	0.361	0.14
Left – right	−0.14	−0.08	[−0.18, −0.09]	−4.64	<0.001	0.69
Fear						
Gaze direction						
Left – centered	0.15	0.17	[0.09, 0.20]	−4.08	<0.001	0.61
Right – centered	0.20	0.17	[0.14, 0.25]	−4.97	<0.001	0.74
Left – right	−0.05	−0.08	[−0.09, −0.01]	−2.45	0.014	0.37
Neutral						
Gaze direction						
Left – centered	−0.12	−0.08	[−0.16, −0.08]	−4.55	<0.001	0.68
Right – centered	−0.07	−0.08	[−0.10, −0.04]	−4.15	<0.001	0.62
left – right	−0.05	0.00	[−0.10, −0.01]	−2.43	0.015	0.36
Sadness						
Gaze direction						
Left – centered	−0.17	−0.17	[−0.22, −0.12]	−4.70	<0.001	0.70
Right – centered	−0.06	−0.08	[−0.11, −0.01]	−2.01	0.045	0.30
Left – right	−0.11	−0.08	[−0.16, −0.06]	−3.61	<0.001	0.54

Pearson's r is reported as a measure of effect size.

with frontal head orientation were considered, all eight facial expressions of the *RaFD* were assessed (in addition: *surprise, disgust*, and *contempt*), and there were no distractors to choose from. Because of the averted faces in two thirds of our trials, the task was harder, but emotion recognition remained at a high level. In fact, the accuracy rate of emotion recognition was superior to that reported for uncovered faces in some (e.g., Grundmann et al., 2021) but not all other studies (Carbon, 2020; Marini et al., 2021). In line with previous research, we observed a clear recognition advantage for happiness and a recognition disadvantage for fear (e.g., Calvo and Lundqvist, 2008); the other emotions ranged somewhere in between. Compared to the findings from Langner et al. (2010) for frontal head orientation, the recognition rates we obtained in the first experiment were quite similar for happiness and neutral, even slightly better for anger and sadness (about 7–8%), but significantly worse for fear (about 20%). General differences were to be expected since we had presented only four models but three head orientations. Regarding the large difference in the recognition of fear, we strongly assume that due to the similarity of the facial expressions fear and surprise, the inclusion of surprise has led to its confusion with fear. Note that surprise featured as a distractor response option but was never displayed in the stimuli.

The effect – or rather the null-effect – of face aversion is striking: Head orientation relative to the observer had no significant effect on emotion recognition. Emotions were detected just as well with the head faced 45° sideways as with a frontally oriented head. Thus, on the one hand, the visibility of mimic signals is less compromised at 45° than expected, and on the other hand, we seem to be able to flexibly adapt our emotion recognition strategies, for example, by changing the relative weighting of individual signals depending on their visibility. This assumption is in line with findings of a study by Stephan and Caine (2007) on face recognition. They noted that, while identity-specific information from the nose and mouth is fairly robust across head orientations, information from the eyes is more susceptible to view transformations, but the availability of information from the eyes suffers largely only at head orientations beyond 45°.

Gaze direction *per se* had a significant effect on emotion recognition and – contrary to our expectations – influenced emotion recognition more strongly than did head orientation. However, this effect was smaller than expected, what might be attributable to the more ecologically valid conditions that included variable head orientations. This is consistent with findings by Ganel (2011), who observed a lower interaction potential between facial expression and gaze direction when simultaneously varying head orientation. Interestingly, in our study, the emotions that were most poorly recognized were most affected. These results are consistent with the assumption that when uncertainty arises due to a lack of signal clarity, other information such as gaze direction is used for clarification (Ganel et al., 2005; Graham and LaBar, 2007, 2012). Thus, unambiguous emotions appear to be processed without gaze interference, but ambiguous emotions tend to be modulated in their processing by gaze direction. With the exception of fear, the results lend support to our hypothesis of a general recognition advantage with direct gaze, as explicable via attentional binding (Senju and Hasegawa, 2005). This corresponds well with the findings of Campbell et al. (2017) and McCrackin and Itier (2019). The fact that fear without mask was better detected with averted gaze, which cannot be explained by general attention binding across emotions, shows that gaze direction at least for this emotion has to be taken into account when investigating emotion recognition. We suggest that for fear, a prioritized processing of threat signals overrides the effect of attentional binding. Whereas a direct gaze generally facilitates emotion recognition through attentional binding, in the case of fear, a lateral gaze would thus signal more danger and therefore increase perceptual sensitivity. Averted gaze might thereby improve the recognition as a function of sclera exposure, as suggested by Carlson and Aday (2018).

What do our findings imply for the impact of mask wearing? Our data from the second experiment indicate a significant overall reduction in emotion recognition of almost 10% due to partial occlusion by the face mask. The deterioration is smaller compared to most other studies that have examined emotion recognition impairment by masks (Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021; Kim et al., 2022; McCrackin et al., 2022). This discrepancy may be caused by differences in stimulus material or task conditions, which would be compatible with the relatively high emotion detection rate we observed for unmasked faces. However, there may be also other reasons: First, the timing of the data collection could be relevant; since the beginning of the COVID-19 pandemic compensation strategies could have been learned. Second, varying all three variables at the same time provided more ecologically valid conditions, which may have allowed for less restricted emotion recognition. We found this impairment of emotion recognition for all facial expressions except neutral, which was even better recognized with the mask. As for neutral expressions, our results compare favorably with those reported by Carbon (2020) and Marini et al. (2021), who neither observed improvement nor impairment in this case. It is plausible that for the recognition of a neutral facial expression a reduction of visible mimic signals can be beneficial, since we are prone to *emotion overgeneralization* (Zebrowitz et al., 2010). The conclusion that masking of less important facial areas can improve emotion recognition has also been drawn by Kim et al. (2022), who observed an improvement in emotion recognition for happiness when covering the eyes with sunglasses.

With regard to the other emotions, we did not observe the strongest deterioration with happiness (∼3%), as expected, but rather with sadness (∼30%) and anger (∼15%). This strong impairment of sadness and anger recognition is remarkable because it is contrary to theoretical assumptions and empirical findings. However, similar results have been reported in previous studies. A comparable strong mask impairment for sadness and anger was observed by Kim et al. (2022). Marini et al. (2021) also found the strongest impairment for sadness, albeit less pronounced compared to our results. Carbon (2020) has shown that, although sadness was not most affected by the mask, confidence in one's own assessment for sadness decreased the most. Especially in times of the pandemic, overlooking and misinterpreting facial expressions of sadness can be grave. Given the relatively well expressed mimic signals of the face stimuli and the distinctive mimic signals theoretically present in the eye region for both anger and sadness (Ekman and Friesen, 1978), these observations suggest that the relevant signals from the eye region are not used efficiently and that the recognition of sadness and anger in everyday life might depend more on the lower face than usually assumed. A study by Blais et al. (2012) noted that people generally use the mouth more than the eyes for emotion differentiation in basic emotions and that the eye region was insufficiently taken into account compared to an ideal observer. Another explanation for this emotion-specific mask impairment could also be that it is linked to the processing mode of the individual emotions, since mask wearing appears to interrupt holistic processing (Freud et al., 2020; Stajduhar et al., 2021). Consequently, the emotions most impaired would be those that rely more heavily on holistic or configural processing for recognition. There is evidence that anger and sadness are actually processed more on the basis of configural information (Bombari et al., 2013). Happiness, in contrast, can also be well processed on the basis of featural information (Bombari et al., 2013). Anger, however, as opposed to sadness, may still have a detection advantage due to prioritized processing of threat signals. The recognition of happiness was merely slightly impaired, maybe due to the fact that happiness was the only positive emotion among all those presented. We assume that it is easier to distinguish emotions according to valence than to recognize the specific emotion. It is also possible that the typical wrinkles on the outer edge of the eyes, which distinguish a genuine *Duchenne* smile from a social smile (Ekman, 2017), may be more indicative of happiness than previously assumed. At least, the results suggest that, in the case of happiness, we can switch our detection strategy and adapt to the conditions of reduced visual signals. A similar robustness of happiness was also observed in other studies (Marini et al., 2021; Kim et al., 2022; McCrackin et al., 2022). In contrast, Carbon (2020) found a stronger impairment in emotion recognition of happiness, although happiness was the only positive emotion investigated.

What might also contribute to the emotion-specific pattern of recognition impairment observed in our study is that sadness, anger, and fear are most susceptible to be mixed up by untrained observers since they all involve eyebrow movements. Such movements are sometimes difficult to distinguish and can look quite different depending on the person, due to individual differences such as the shape of the eyebrows. In addition, mimic signals also convey a wide variety of non-emotional information (Adams and Nelson, 2011; Knapp et al., 2014), for example about thought processes, especially involving the upper face (Rinn, 1984). The absence of information about the lower face increases ambiguity. In sum, available signals are not necessarily used optimally, which may not be a challenge until we are confronted with unfamiliar conditions such as wearing masks. Conversely, this also means that there is a lot of potential for learning.

With regard to the interaction between the mask and the extraneous cues gaze direction and head orientation, we found remarkable results. For masked faces, the influence of both gaze direction and head orientation on emotion recognition increased. Again, the emotions that were most poorly recognized – with mask different ones than for unmasked faces – were most affected by gaze direction, as evidenced by a significant mask × emotion × gaze direction three-way interaction. Thus, in line with our hypothesis, in the case of decreased discriminability and increased ambiguity of the displayed emotions the extraneous cues gained more influence. However, note that the increase for head orientation was too small to produce any significant mask interaction in the mixed ANCOVA, although it caused a significant main effect of head orientation as well as a significant emotion × head orientation interaction in the rmANOVA for masked stimuli. It is also important to emphasize that our data show that factoring in such additional information not necessarily improves the performance but can also impair it even more. As for gaze direction, emotion recognition tended to deteriorate with gaze deflection for all emotions except fear. Thus, in case of uncertainty, we seem to unconsciously integrate extraneous information into our emotion processing regardless of whether or not it is helpful.

As for head orientation, the increased influence cannot be explained with the reduction of ambiguity alone. The change in signal strength in the eye region during head rotation might become more influential when the information of the mouth-nose region is lacking, and therefore may also contribute to the greater impact of head orientation. Stephan and Caine (2007) reported that, in terms of identity recognition, the change in the visibility of information from the eyes with head rotation only affects recognition performance when the head is turned more than 45° sideways, but the story might be different in terms of emotion recognition. Thus, it remains unclear to what extent the face occlusion exerts its influence via the altered signal visibility and to what extent via reassignment of signal relevance during cue integration as necessitated by mask wearing. A reassignment or reweighting would be supported by the fact that, with mask, all emotions except anger tended to be better recognized with averted head than with frontal head. In contrast, without mask, such tendencies were only observable for anger and neutral. We suppose that up to an angle of 45° head rotation, the visibility of the signals changes so slightly that it does not significantly affect emotion recognition, but clearly alters the relative salience of certain signals from the eye region. The typical wrinkles in the eye area associated with happiness are mainly located at the outer edge of the eyes and may be more exposed when viewed from the side. In the prototypical expression of anger, in contrast, the eyebrows are lowered and contracted, shifting the focus of the signals to the center between the eyes, which is probably less salient with the head turned sideways as compared to the head facing forward. Consequently, our results suggest that, overall, the mask has the greatest effect on emotion recognition when the head is facing frontally and that mask-induced impairment is attenuated under ecologically valid conditions when the head can turn freely.

To conclude, mask wearing not only impaired emotion recognition in an unexpected emotion-specific way, but it also altered interaction effects between facial expressions and extraneous cues both quantitatively and qualitatively.

Limitations, implications, and recommendations

There are some limitations, of which the most important will be pointed out. We consider the type of manipulation of gaze direction and head orientation, which is tied to the stimulus material of the *RaFD,* as the major limitation of this study. This is because these two variables do not vary independently of each other. Gaze direction is attached to and defined in dependence of head orientation. It always shifts at the same deviation angle of about 13° relative to the head, while the head rotates at a 45° angle. Since we had also selected only one head deviation angle (−45°, 0°, and 45°), there is neither a continuous gradation of head orientation nor of gaze direction or of the relative distance between both. Thus, individual effects cannot be considered as a function of a continuous change in those parameters, which should be kept in mind regarding interpretation and generalizability. Our results suggest that more head and gaze angles should be tested in future research.

Another shortcoming of our study is the restriction to four face models. We found that in some models certain emotions were particularly poorly recognized, which suggests that the models differed in facial features relevant to emotion recognition, as is also to be expected with different faces in everyday life. However, given that the emotions were acted and given that for practical reasons, a larger or representative sample of actors was prohibitive, differences among the models cannot be interpreted. Many factors could be responsible for such differences, for instance invariant features such as eye color and shape or eye and pupil distance, or variable features like mimic movements. Even though the models had been trained by FACS experts (Facial Action Coding System) and the displayed facial expressions had been validated (Langner et al., 2010), they still differ in their emotional expressions as well as in their neutral expression (Jaeger, 2020). Since the eye region is considered the most variable facial area (Itier and Batty, 2009), model differences could be particularly relevant when faces are covered by a mask. This would be consistent with our finding that mask wearing led to more variation in emotion recognition performance between models.

Furthermore, this study is subject to the inherent limitations of any online experiment. It did not allow for tight experimental control of viewing distance and monitor resolution, and potential distractions during the experiment. This might have added noise to the data, however, we have no indication that this noise could have been systematic. Other limitations are associated with the use of photographs with posed facial expressions and superimposed face masks. Enacting emotional expressions may be the only way to produce a large database, however, in everyday life, we may be confronted with expressions that go beyond an actor's ability, that are less intense or fragmentary (subtle emotions), or that merely last for a fraction of a second (microexpressions). Moreover, emotional facial expressions are usually not the focus of attention. In real life, the effects of mask wearing on emotion recognition may therefore be more pronounced. Or they may be compensated by adaptation strategies both in sending and receiving emotional facial signals – or by integrating more other emotional cues such as body posture. Especially sadness seems to be very well recognizable on the basis of body posture (de Gelder and Van den Stock, 2011), which in daily social interactions could compensate for the strong impairment observed in this study. Adaptation strategies as a consequence of mask wearing have been observed by Kulke et al. (2021), who reported a slight improvement in emotion recognition from the eyes, which was, however, limited to women. Also, Okazaki et al. (2021) found a stronger eye involvement in smiling (as measured by orbicularis oculi activity) when wearing a mask. In contrast, Levitan et al. (2022) observed that masked positive faces were rated as less positive than unmasked positive faces regardless of whether the whole face or only the upper face was presented, which they attributed to reduced positive emotion and/or reduced expressivity of positive emotion as a consequence of wearing a mask. Further studies investigating such adaptation processes will be necessary.

May the high proportion of females be a problem? There is a consistent female advantage in recognizing emotions in particular when the face is partially covered (Grundmann et al., 2021). Moreover, men tend to look more often and longer at the mouth and especially at the nose during emotion recognition (Vassallo et al., 2009), whereas women tend to look more at the eyes (Hall et al., 2010). This would even suggest a greater mask impairment in males and thus more pronounced gender differences with masked faces. It is therefore reasonable to assume that in gender-balanced samples, the effects we have found could only be more pronounced.

Insights into the emotion-specific recognition impairment by masks broadens our understanding of how efficiently available mimic signals can be used in intuitive emotion perception by untrained observers. This allows for purposive emotional training to strengthen those emotional competences that are particularly affected by wearing a mask. The results of our study indicate that facial expression, gaze direction, and head orientation are closely linked at the perceptual level and that their simultaneous inclusion can make a difference. Therefore, future studies might benefit from a design that simultaneously considers all three variables. Further studies will be necessary to gain insights into adaptation to and compensation of the cue reduction caused by mandatory mask wearing. They should explore whether and how long such adaptation strategies will persist after the pandemic crisis.

Conclusion

The results of our study add to and qualify the existing body of literature on the impact of mask wearing on emotion recognition. It is indispensable to take into account gaze direction and head orientation as extraneous cues highly relevant in facial perception in real-life situations. Emotion recognition was surprisingly well adapted to the altered visibility of facial signals due to head and gaze deflection, with gaze direction only slightly influencing the emotions that were most poorly recognized. However, when the facial signals of the lower face were completely absent due to mask wearing, emotion recognition was clearly impaired, with sadness and anger being the most affected emotions. Moreover, the mask also amplified the influence of gaze direction and head orientation. Thus, when there is increased uncertainty due to ambiguity or absence of signals, extraneous cues are more likely to be integrated in the perceptual process of judging emotion from facial features.

Data availability statement

The original data presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding author.

Ethics statement

The study was conducted in line with the ethical standards of the local ethics board of the Psychological Institute of Mainz University. Since voluntary participation on a fully informed basis and anonymity were assured, and there was no risk for physical stress or disadvantages due to group assignment, the research fell under the blanket approval of the ethics board. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

HH, CC, and LT designed the experiments and edited the manuscript. LT implemented and conducted the experiments, analyzed the data, and drafted the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnins.2022.937939/full#supplementary-material

References

Adams, R. B., Albohn, D. N., and Kveraga, K. (2017). Social vision: Applying a social-functional approach to face and expression perception. *Curr. Direct. Psychol. Sci.* 26, 243–248. doi: 10.1177/0963721417706392

Adams, R. B., Ambady, N., Macrae, C. N., and Kleck, R. E. (2006). Emotional expressions forecast approach-avoidance behavior. *Motiv. Emot.* 30, 177–186. doi: 10.1007/s11031-006-9020-2

Adams, R. B., Franklin, R. G., Nelson, A. J., and Stevenson, M. T. (2010b). "Compound social cues in human face processing," in *The Science of Social Vision*, eds R. B. Adams, N. Ambady, K. Nakayama, and S. Shimojo (Oxford: Oxford University Press), 90–107. doi: 10.1093/acprof:oso/9780195333176.003.0006

Adams, R. B., Ambady, N., Nakayama, K., and Shimojo, S. (2010a). *The science of social vision*. Oxford: Oxford University Press, doi: 10.1093/acprof:oso/9780195333176.001.0001

Adams, R. B., and Franklin, R. G. (2009). Influence of emotional expression on the processing of gaze direction. *Motiv. Emot.* 33, 106–112. doi: 10.1007/s11031-009-9121-9

Adams, R. B., and Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychol. Sci.* 14, 644–647. doi: 10.1046/j.0956-7976.2003.psci_1479.x

Adams, R. B., and Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion* 5, 3–11. doi: 10.1037/1528-3542.5.1.3

Adams, R. B., and Kveraga, K. (2015). Social vision: Functional forecasting and the integration of compound social cues. *Rev. Philos. Psychol.* 6, 591–610. doi: 10.1007/s13164-015-0256-1

Adams, R. B., and Nelson, A. J. (2011). "Intersecting identities and expressions: The compound nature of social perception," in *The Oxford Handbook of Social Neuroscience*, eds J. Decety and J. T. Cacioppo (Oxford: Oxford University Press), doi: 10.1093/oxfordhb/9780195342161.013.0026

Adams, R. B., Gordon, H. L., Baird, A. A., Ambady, N., and Kleck, R. E. (2003). Effects of gaze on amygdala sensitivity to anger and fear faces. *Science* 300, 1536–1536. doi: 10.1126/science.1082244

Alais, D., Kong, G., Palmer, C., and Clifford, C. (2018). Eye gaze direction shows a positive serial dependency. *J. Vis.* 18:11. doi: 10.1167/18.4.11

Anstis, S. M., Mayhew, J. W., and Morley, T. (1969). The perception of where a face or television „portrait" is looking. *Am. J. Psychol.* 82:474. doi: 10.2307/1420441

Aviezer, H., Hassin, R. R., Ryan, J., Grady, C., Susskind, J., Anderson, A., et al. (2008). Angry, disgusted, or afraid? Studies on the malleability of emotion perception. *Psychol. Sci.* 19, 724–732. doi: 10.1111/j.1467-9280.2008.02148.x

Bassili, J. N. (1979). Emotion recognition: The role of facial movement and the relative importance of upper and lower areas of the face. *J. Person. Soc. Psychol.* 37, 2049–2058. doi: 10.1037//0022-3514.37.11.2049

Benton, C. P. (2010). Rapid reactions to direct and averted facial expressions of fear and anger. *Visual Cognition* 18, 1298–1319. doi: 10.1080/13506285.2010.481874

Bindemann, M., Mike Burton, A., and Langton, S. R. H. (2008). How do eye gaze and facial expression interact?. *Vis. Cogn.* 16, 708–733. doi: 10.1080/13506280701269318

Blais, C., Roy, C., Fiset, D., Arguin, M., and Gosselin, F. (2012). The eyes are not the window to basic emotions. *Neuropsychologia* 50, 2830–2838. doi: 10.1016/j.neuropsychologia.2012.08.010

Bombari, D., Schmid, P. C., Schmid Mast, M., Birri, S., Mast, F. W., and Lobmaier, J. S. (2013). Emotion recognition: The role of featural and configural face information. *Q. J. Exp. Psychol.* 66, 2426–2442. doi: 10.1080/17470218.2013.789065

Brodeur, A., Gray, D., Islam, A., and Bhuiyan, S. (2021). A literature review of the economics of COVID-19. *J. Econ. Surv.* 35, 1007–1044. doi: 10.1111/joes.12423

Bublatzky, F., Pittig, A., Schupp, H. T., and Alpers, G. W. (2017). Face-to-face: Perceived personal relevance amplifies face processing. *Soc. Cogn. Affect. Neurosci.* 12, 811–822. doi: 10.1093/scan/nsx001

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: An online study on face covering. *Sci. Rep.* 11:2601. doi: 10.1038/s41598-021-81780-w

Calvo, M. G., and Lundqvist, D. (2008). Facial expressions of emotion (KDEF): Identification under different display-duration conditions. *Behav. Res. Methods* 40, 109–115. doi: 10.3758/BRM.40.1.109

Calvo, M. G., and Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *J. Exp. Psychol.* 137, 471–494. doi: 10.1037/a0012771

Calvo, M. G., Fernández-Martín, A., and Nummenmaa, L. (2014). Facial expression recognition in peripheral versus central vision: Role of the eyes and the mouth. *Psychol. Res.* 78, 180–195. doi: 10.1007/s00426-013-0492-x

Campbell, A., Murray, J. E., Atkinson, L., and Ruffman, T. (2017). Face age and eye gaze influence older adults' emotion recognition. *J. Gerontol.* 72, 633–636. doi: 10.1093/geronb/gbv114

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carlson, J. M., and Aday, J. (2018). In the presence of conflicting gaze cues, fearful expression and eye-size guide attention. *Cogn. Emot.* 32, 1178–1188. doi: 10.1080/02699931.2017.1391065

Carragher, D. J., and Hancock, P. J. B. (2020). Surgical face masks impair human face matching performance for familiar and unfamiliar faces. *Cogn. Res.* 5:59. doi: 10.1186/s41235-020-00258-x

Caruana, N., Inkley, C., Zein, M. E., and Seymour, K. (2019). No influence of eye gaze on emotional face processing in the absence of conscious awareness. *Sci. Rep.* 9:16198. doi: 10.1038/s41598-019-52728-y

de Gelder, B., and Van den Stock, J. (2011). The bodily expressive action stimulus test (BEAST). Construction and validation of a stimulus basis for measuring perception of whole body expression of emotions. *Front. Psychol.* 2:181. doi: 10.3389/fpsyg.2011.00181

de Gelder, B., and Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cogn. Emot.* 14, 289–311. doi: 10.1080/026999300378824

Eisenbarth, H., and Alpers, G. W. (2011). Happy mouth and sad eyes: Scanning emotional facial expressions. *Emotion* 11, 860–865. doi: 10.1037/a0022758

Ekman, P. (2017). *Gefühle lesen: Wie Sie Emotionen erkennen und richtig interpretieren*. Berlin: Springer.

Ekman, P., and Friesen, W. (1978). *Facial action coding system: A technique for the measurement of facial movement*. California, CA: Consulting Psychologists Press.

Ekman, P., Friesen, W. V., and Hager, J. C. (2002). *Facial action coding system: The manual*. Salt Lake City, UT: Research Nexus.

El Zein, M., Wyart, V., and Grèzes, J. (2015). Anxiety dissociates the adaptive functions of sensory and motor response enhancements to social threats. *ELife* 4:e10274. doi: 10.7554/eLife.10274

Faul, F., Erdfelder, E., Lang, A.-G., and Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Fischer, A. H., Gillebaart, M., Rotteveel, M., Becker, D., and Vliek, M. (2012). Veiled emotions: The effect of covered faces on emotion perception and attitudes. *Soc. Psychol. Person. Sci.* 3, 266–273. doi: 10.1177/1948550611418534

Freud, E., Stajduhar, A., Rosenbaum, R. S., Avidan, G., and Ganel, T. (2020). The COVID-19 pandemic masks the way people perceive faces. *Sci. Rep.* 10:22344. doi: 10.1038/s41598-020-78986-9

Gamer, M., and Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *J. Exp. Psychol.* 33, 705–715. doi: 10.1037/0096-1523.33.3.705

Ganel, T. (2011). Revisiting the relationship between the processing of gaze direction and the processing of facial expression. *J. Exp. Psychol.* 37, 48–57. doi: 10.1037/a0019962

Ganel, T., Goshen-Gottstein, Y., and Goodale, M. A. (2005). Interactions between the processing of gaze direction and facial expression. *Vis. Res.* 45, 1191–1200. doi: 10.1016/j.visres.2004.06.025

Gosselin, F., and Schyns, P. G. (2001). Bubbles: A technique to reveal the use of information in recognition tasks. *Vis. Res.* 41, 2261–2271. doi: 10.1016/S0042-6989(01)00097-9

Graham, R., and LaBar, K. S. (2007). Garner interference reveals dependencies between emotional expression and gaze in face perception. *Emotion* 7, 296–313. doi: 10.1037/1528-3542.7.2.296

Graham, R., and LaBar, K. S. (2012). Neurocognitive mechanisms of gaze-expression interactions in face processing and social attention. *Neuropsychologia* 50, 553–566. doi: 10.1016/j.neuropsychologia.2012.01.019

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hall, J. K., Hutton, S. B., and Morgan, M. J. (2010). Sex differences in scanning faces: Does attention to the eyes explain female superiority in facial expression recognition?. *Cogn. Emot.* 24, 629–637. doi: 10.1080/02699930902906882

Harari, D., Gao, T., Kanwisher, N., Tenenbaum, J., and Ullman, S. (2016). Measuring and modeling the perception of natural and unconstrained gaze in humans and machines. *arXiv* [Preprint]. doi: 10.48550/arXiv.1611.09819

Hassin, R. R., Aviezer, H., and Bentin, S. (2013). Inherently ambiguous: Facial expressions of emotions, in context. *Emot. Rev.* 5, 60–65. doi: 10.1177/1754073912451331

Hecht, H., Wilhelm, A., and von Castell, C. (2021). Inverting the Wollaston illusion: Gaze direction attracts perceived head orientation. *I Percept.* 12:204166952110469. doi: 10.1177/20416695211046975

Hess, U., Adams, R. B., and Kleck, R. E. (2007). Looking at you or looking elsewhere: The influence of head orientation on the signal value of emotional facial expressions. *Motiv. Emot.* 31, 137–144. doi: 10.1007/s11031-007-9057-x

Hochberg, Y. (1988). A sharper Bonferroni procedure for multiple tests of significance. *Biometrika* 75, 800–802. doi: 10.1093/biomet/75.4.800

Itier, R. J., and Batty, M. (2009). Neural bases of eye and gaze processing: The core of social cognition. *Neurosci. Biobehav. Rev.* 33, 843–863. doi: 10.1016/j.neubiorev.2009.02.004

Jaeger, B. (2020). Trait ratings for the Radboud Faces Database. *PsyArXiv* [Preprint]. doi: 10.17605/OSF.IO/CF5AD

Jenkins, J., and Langton, S. R. H. (2003). Configural processing in the perception of eye-gaze direction. *Perception* 32, 1181–1188. doi: 10.1068/p3398

Kim, G., Seong, S. H., Hong, S. S., and Choi, E. (2022). Impact of face masks and sunglasses on emotion recognition in South Koreans. *PLoS One* 17:e0263466. doi: 10.1371/journal.pone.0263466

Knapp, M. L., Hall, J. A., and Horgan, T. G. (2014). *Nonverbal communication in human interaction*, (8. Edn). Boston, MA: Wadsworth/Cengage Learning.

Kret, M. E., and de Gelder, B. (2012). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Kret, M. E., Maitner, A. T., and Fischer, A. H. (2021). Interpreting emotions from women with covered faces: A comparison between a Middle Eastern and Western-European sample. *Front. Psychol.* 12:620632. doi: 10.3389/fpsyg.2021.620632

Kulke, L., Langer, T., and Valuch, C. (2021). The emotional lockdown: How social distancing and mask wearing influence mood and emotion recognition. *PsyArXiv* [Preprint]. doi: 10.31234/osf.io/cpxry

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., and van Knippenberg, A. (2010). Presentation and validation of the Radboud Faces Database. *Cogn. Emot.* 24, 1377–1388. doi: 10.1080/02699930903485076

Langton, S. R. H. (2000). The mutual influence of gaze and head orientation in the analysis of social attention direction. *Q. J. Exp. Psychol. Sec. A* 53, 825–845. doi: 10.1080/713755908

Langton, S. R. H., Watt, R., and Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends Cogn. Sci.* 4, 50–59. doi: 10.1016/S1364-6613(99)01436-9

Levitan, C. A., Rusk, I., Jonas-Delson, D., Lou, H., Kuzniar, L., Davidson, G., et al. (2022). Mask wearing affects emotion perception. *I Percept.* 13:204166952211073. doi: 10.1177/20416695221107391

Loomis, J. M., Kelly, J. W., Pusch, M., Bailenson, J. N., and Beall, A. C. (2008). Psychophysics of perceiving eye-gaze and head direction with peripheral vision: Implications for the dynamics of eye-gaze behavior. *Perception* 37, 1443–1457. doi: 10.1068/p5896

Lopes, P. N., Brackett, M. A., Nezlek, J. B., Schütz, A., Sellin, I., and Salovey, P. (2004). Emotional intelligence and social interaction. *Person. Soc. Psychol. Bull.* 30, 1018–1034. doi: 10.1177/0146167204264762

Lopes, P. N., Salovey, P., Côté, S., and Beers, M. (2005). Emotion regulation abilities and the quality of social interaction. *Emotion* 5, 113–118. doi: 10.1037/1528-3542.5.1.113

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Mayer, J. D., Roberts, R. D., and Barsade, S. G. (2008). Human abilities: Emotional intelligence. *Annu. Rev. Psychol.* 59, 507–536. doi: 10.1146/annurev.psych.59.103006.093646

McCrackin, S. D., and Itier, R. J. (2019). Perceived gaze direction differentially affects discrimination of facial emotion, attention, and gender – An ERP study. *Front. Neurosci.* 13:517. doi: 10.3389/fnins.2019.00517

McCrackin, S. D., Capozzi, F., Mayrand, F., and Ristic, J. (2022). Face masks impair basic emotion recognition: Group effects and individual variability. *Soc. Psychol.* doi: 10.1027/1864-9335/a000470 [Epub ahead of print].

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L. H., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Nusseck, M., Cunningham, D. W., Wallraven, C., and Bülthoff, H. H. (2008). The contribution of different facial regions to the recognition of conversational expressions. *J. Vis.* 8, 1–23. doi: 10.1167/8.8.1

Okazaki, S., Yamanami, H., Nakagawa, F., Takuwa, N., and Kawabata Duncan, K. J. (2021). Mask wearing increases eye involvement during smiling: A facial EMG study. *Sci. Rep.* 11:20370. doi: 10.1038/s41598-021-99872-y

Ortony, A., and Turner, T. J. (1990). What's basic about basic emotions?. *Psychol. Rev.* 97, 315–331. doi: 10.1037/0033-295X.97.3.315

Otsuka, Y., Mareschal, I., and Clifford, C. W. G. (2016). Testing the dual-route model of perceived gaze direction: Linear combination of eye and head cues. *J. Vis.* 16:8. doi: 10.1167/16.8.8

Parkinson, B. (1996). Emotions are social. *Br. J. Psychol.* 87, 663–683. doi: 10.1111/j.2044-8295.1996.tb02615.x

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Pedrosa, A. L., Bitencourt, L., Fróes, A. C. F., Cazumbá, M. L. B., Campos, R. G. B., de Brito, S. B. C. S., et al. (2020). Emotional, behavioral, and psychological impact of the COVID-19 pandemic. *Front. Psychol.* 11:566212. doi: 10.3389/fpsyg.2020.566212

Putman, P., Hermans, E., and van Honk, J. (2006). Anxiety meets fear in perception of dynamic expressive gaze. *Emotion* 6, 94–102. doi: 10.1037/1528-3542.6.1.94

Rajkumar, R. P. (2020). COVID-19 and mental health: A review of the existing literature. *Asian J. Psychiatry* 52:102066. doi: 10.1016/j.ajp.2020.102066

Ricciardelli, P., Lugli, L., Pellicano, A., Iani, C., and Nicoletti, R. (2016). Interactive effects between gaze direction and facial expression on attentional resources deployment: The task instruction and context matter. *Sci. Rep.* 6:21706. doi: 10.1038/srep21706

Rinn, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychol. Bull.* 95, 52–77. doi: 10.1037/0033-2909.95.1.52

Schurgin, M. W., Nelson, J., Iida, S., Ohira, H., Chiao, J. Y., and Franconeri, S. L. (2014). Eye movements during emotion recognition in faces. *J. Vis.* 14:14. doi: 10.1167/14.13.14

Schwaninger, A., Lobmaier, J. S., and Fischer, M. H. (2005). The inversion effect on gaze perception reflects processing of component information. *Exp. Brain Res.* 167, 49–55. doi: 10.1007/s00221-005-2367-x

Senju, A., and Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Vis. Cogn.* 12, 127–144. doi: 10.1080/13506280444000157

Seyama, J., and Nagayama, R. (2005). The effect of torso direction on the judgement of eye direction. *Vis. Cogn.* 12, 103–116. doi: 10.1080/13506280444000111

Smith, M. L., Cottrell, G. W., Gosselin, F., and Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychol. Sci.* 16, 184–189. doi: 10.1111/j.0956-7976.2005.00801.x

Stajduhar, A., Ganel, T., Avidan, G., Rosenbaum, R., and Freud, E. (2021). Face masks disrupt holistic processing and face perception in school-age children. *PsyArXiv* [Preprint]. doi: 10.31234/osf.io/fygjq

Stephan, B. C. M., and Caine, D. (2007). What is in a view? The role of featural information in the recognition of unfamiliar faces across viewpoint transformation. *Perception* 36, 189–198. doi: 10.1068/p5627

Surcinelli, P., Andrei, F., Montebarocci, O., and Grandi, S. (2021). Emotion recognition of facial expressions presented in profile. *Psychol. Rep.* 26:332941211018403. doi: 10.1177/00332941211018403

Sweeny, T. D., and Whitney, D. (2017). The center of attention: Metamers, sensitivity, and bias in the emergent perception of gaze. *Vis. Res.* 131, 67–74. doi: 10.1016/j.visres.2016.10.014

Symons, L. A., Lee, K., Cedrone, C. C., and Nishimura, M. (2004). What are you looking at? Acuity for triadic eye gaze. *J. Gen. Psychol.* 131, 451–469.

Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cogn. Emot.* 20, 309–320. doi: 10.1080/02699930500405550

Todorović, D. (2006). Geometrical basis of perception of gaze direction. *Vis. Res.* 46, 3549–3562. doi: 10.1016/j.visres.2006.04.011

Todorović, D. (2009). The effect of face eccentricity on the perception of gaze direction. *Perception* 38, 109–132. doi: 10.1068/p5930

Tracy, J. L., and Randles, D. (2011). Four models of basic emotions: A review of Ekman and Cordaro, Izard, Levenson, and Panksepp and Watt. *Emot. Rev.* 3, 397–405. doi: 10.1177/1754073911410747

Tsantani, M., Podgajecka, V., Gray, K. L. H., and Cook, R. (2022). How does the presence of a surgical face mask impair the perceived intensity of facial emotions?. *PLoS One* 17:e0262344. doi: 10.1371/journal.pone.0262344

Van Kleef, G. A. (2009). How emotions regulate social life: The emotions as social information (EASI) model. *Curr. Direct. Psychol. Sci.* 18, 184–188. doi: 10.1111/j.1467-8721.2009.01633.x

Van Kleef, G. A., Cheshin, A., Fischer, A. H., and Schneider, I. K. (2016). Editorial: The social nature of emotions. *Front. Psychol.* 7:896. doi: 10.3389/fpsyg.2016.00896

Vassallo, S., Cooper, S. L., and Douglas, J. M. (2009). Visual scanning in the recognition of facial affect: Is there an observer sex difference?. *J. Vis.* 9:11. doi: 10.1167/9.3.11

Vindegaard, N., and Benros, M. E. (2020). COVID-19 pandemic and mental health consequences: Systematic review of the current evidence. *Brain Behav. Immun.* 89, 531–542. doi: 10.1016/j.bbi.2020.05.048

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Welsch, R., Hecht, H., Chuang, L., and von Castell, C. (2020). Interpersonal distance in the SARS-CoV-2 crisis. *Hum. Fact.* 62, 1095–1101. doi: 10.1177/0018720820956858

Welsch, R., Wessels, M., Bernhard, C., Thönes, S., and von Castell, C. (2021). Physical distancing and the perception of interpersonal distance in the COVID-19 crisis. *Sci. Rep.* 11:11485. doi: 10.1038/s41598-021-90714-5

Wessels, M., Utegaliyev, N., Bernhard, C., Welsch, R., Oberfeld, D., Thönes, S., et al. (2022). Adapting to the pandemic: Longitudinal effects of social restrictions on time perception and boredom during the Covid-19 pandemic in Germany. *Sci. Rep.* 12:1863. doi: 10.1038/s41598-022-05495-2

West, R. W. (2013). The effect of head turn and illumination on the perceived direction of gaze. *Perception* 42, 495–507. doi: 10.1068/p7343

Wilson, H. R., Wilkinson, F., Lin, L. M., and Castillo, M. (2000). Perception of head orientation. *Vis. Res.* 40, 459–472. doi: 10.1016/s0042-6989(99)00195-9

World Health Organization [WHO] (2022). *WHO Coronavirus (COVID-19) Dashboard*. Geneva: World Health Organization.

Xiong, J., Lipsitz, O., Nasri, F., Lui, L. M. W., Gill, H., Phan, L., et al. (2020). Impact of COVID-19 pandemic on mental health in the general population: A systematic review. *J. Affect. Disord.* 277, 55–64. doi: 10.1016/j.jad.2020.08.001

Zebrowitz, L. A., Kikuchi, M., and Fellous, J. M. (2010). Facial resemblance to emotions: Group differences, impression effects, and race stereotypes. *J. Person. Soc. Psychol.* 98, 175–189. doi: 10.1037/a0017990

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COVID-19 masks: A barrier to facial and vocal information

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With the COVID-19 pandemic, we have become used to wearing masks and have experienced how masks seem to impair emotion and speech recognition. While several studies have focused on facial emotion recognition by adding images of masks on photographs of emotional faces, we have created a video database with actors really wearing masks to test its effect in more ecological conditions. After validating the emotions displayed by the actors, we found that surgical mask impaired happiness and sadness recognition but not neutrality. Moreover, for happiness, this effect was specific to the mask and not to covering the lower part of the face, possibly due to a cognitive bias associated with the surgical mask. We also created videos with speech and tested the effect of mask on emotion and speech recognition when displayed in auditory, visual, or audiovisual modalities. In visual and audiovisual modalities, mask impaired happiness and sadness but improved neutrality recognition. Mask impaired the recognition of bilabial syllables regardless of modality. In addition, it altered speech recognition only in the audiovisual modality for participants above 70 years old. Overall, COVID-19 masks mainly impair emotion recognition, except for older participants for whom it also impacts speech recognition, probably because they rely more on visual information to compensate age-related hearing loss.

KEYWORDS

speech, emotion, face, voice, occlusion, age

Introduction

Faces and voices are primary vectors of information crucial for social interaction and communication. Since March 2020, due to the COVID-19 pandemic, the world is moving forward masked. To prevent virus spread, national health agencies in multiple countries recommend wearing a mask that covers the mouth and nose. While face covering occurs in normal situation depending on cultural contexts or environment, such as wearing a scarf, sunglasses, or a niqab, wearing a surgical mask gives the general impression of larger disruption of social interaction (Saunders et al., 2021). Faces are processed holistically (as a whole) rather than analytically (feature by feature; Maurer et al., 2002). Facial expressions have been shown to involve both analytical and holistic processing depending on the emotion (Meaux and Vuilleumier, 2016). Diagnostic features for a particular emotion are in specific parts of the face (Blais et al., 2012); for instance, while happiness recognition seems to rely more on the bottom part of the face, the recognition of sadness or fear appears to depend more on the eye region (Bombari et al., 2013). Face covering may therefore impact the type of processes involved in facial perception by hindering global information and making it more dependent on facial features; in addition, covering the bottom or top part of the face may have differential effect on emotion recognition. It thus appears crucial to compare the effect of wearing a mask to wearing other accessories that cover different parts of the face. A face mask also impedes the transmission of acoustical information from the voice (e.g., Nguyen et al., 2021) and hides articulatory movements of the mouth, important for lip reading and speech comprehension. Therefore, face masking can impact face and voice information processing, as well as the audiovisual integration of social information.

Recently, there was a surge in research about the effect of mask on facial information recognition and in particular emotions (Carbon, 2020; Fitousi et al., 2021; Gori et al., 2021; Grundmann et al., 2021; Kastendieck et al., 2021; Marini et al., 2021; Noyes et al., 2021; Pazhoohi et al., 2021), with many studies reporting impaired emotion and identity recognition in masked faces. Partial occlusion of the face (Fischer et al., 2012; Kret and de Gelder, 2012a) is known to disrupt more the recognition of positive emotions than negative ones. Consistently, a surgical mask appears to impact more the recognition of happiness than negative emotions (Fitousi et al., 2021; Marini et al., 2021; Grenville and Dwyer, 2022; Levitan et al., 2022; Ross and George, 2022), except sadness for which mixed results are reported (e.g., Marini et al., 2021; Grenville and Dwyer, 2022; Ross and George, 2022). In most studies, authors artificially added masks on still face photographs from existing face databases. Although allowing a comparison of controlled and identical emotional content between masked and non-masked conditions, these protocols using retouched images do not fully investigate ecological facial emotion recognition. First, really worn facial masks do not completely mask important structural information (Fitousi et al., 2021); note that no differences between real-worn and artificially added mask on still photographs were observed (Grenville and Dwyer, 2022). Second, facial expressions are better recognized on dynamic stimuli, especially when they are subtle (Bould and Morris, 2008). Consistently, physiological reactivity, reflecting automatic face processing, is sensitive to both the realism and the dynamism of a face (Aguillon-Hernandez et al., 2020), recommending the use of videos over photographs to study emotion perception. Therefore, using videos of persons really wearing masks appears more optimal and ecological to study the impact of face masking on facial emotion recognition. In addition, as has been done in a few studies (Roberson et al., 2012; Noyes et al., 2021), the use of other elements to mask the face (sunglasses or scarf) allows better control of the specific impact of the COVID-19 mask. Comparing different accessories (mask or scarf) to occlude the bottom half of the face might reveal a supplementary hindrance of the mask, possibly due to its negative psychological value (Saunders et al., 2021).

Using videos allows to investigate the effects of masks on audiovisual perception of both emotion and speech. This is important as in ecological context, faces are rarely seen in isolation and are often coupled with other cues. Audiovisual integration is particularly important in situation where the signal in one modality is degraded (de Boer et al., 2021), as is the case when the face is masked, stressing the importance of testing recognition with audiovisual stimuli. Adding information, for example, body cues in a purely visual context, has been shown to decrease the impact of face masks on emotion recognition (Ross and George, 2022).

This study aimed to measure the effect of wearing a surgical mask on the recognition of (1) visual facial emotion, with respect to other face covering accessories; (2) emotion; and (3) speech in voices, faces, and audiovisual stimuli, using a video database developed exclusively for the study. We hypothesized that face covering will impact facial emotion recognition, with differential effects for covering the bottom or top part of the face, and possibly a larger effect for mask. In the audiovisual emotion recognition task, we expected better emotion recognition in audiovisual than in visual-only condition as the auditory input would compensate for masking the mouth. In the audiovisual speech recognition task, we thought the mask could interfere with syllable recognition as the mask is known to alter transmission of acoustical information.

Materials and methods

Stimuli

We created two sets of videos by filming six actors (three males), starting in a neutral state and either staying neutral or expressing emotions (happiness or sadness; chosen as they do not yield avoiding behavior) before returning to neutral. During filming, actors worn the accessories and thus expressed the emotions as the accessories allowed them to do, mimicking as much as possible real-life emotional expression, without exaggerating emotional intensity. For neutral expressions, actors stayed neutral and unmoving, but the small motion of the face muscles could be observed. Actors were told to produce the same emotions in all conditions. They had to observe a visual cue (without producing saccades) moving on a Gaussian curve to induce emotional expression with the same dynamic and intensity in each condition. In Set 1 (**Figure 1A**), they were silent and wore an accessory (sunglasses/scarf/mask) or not. A total of 72 videos were created: 6 actors × 3 emotions × 4 accessories. In

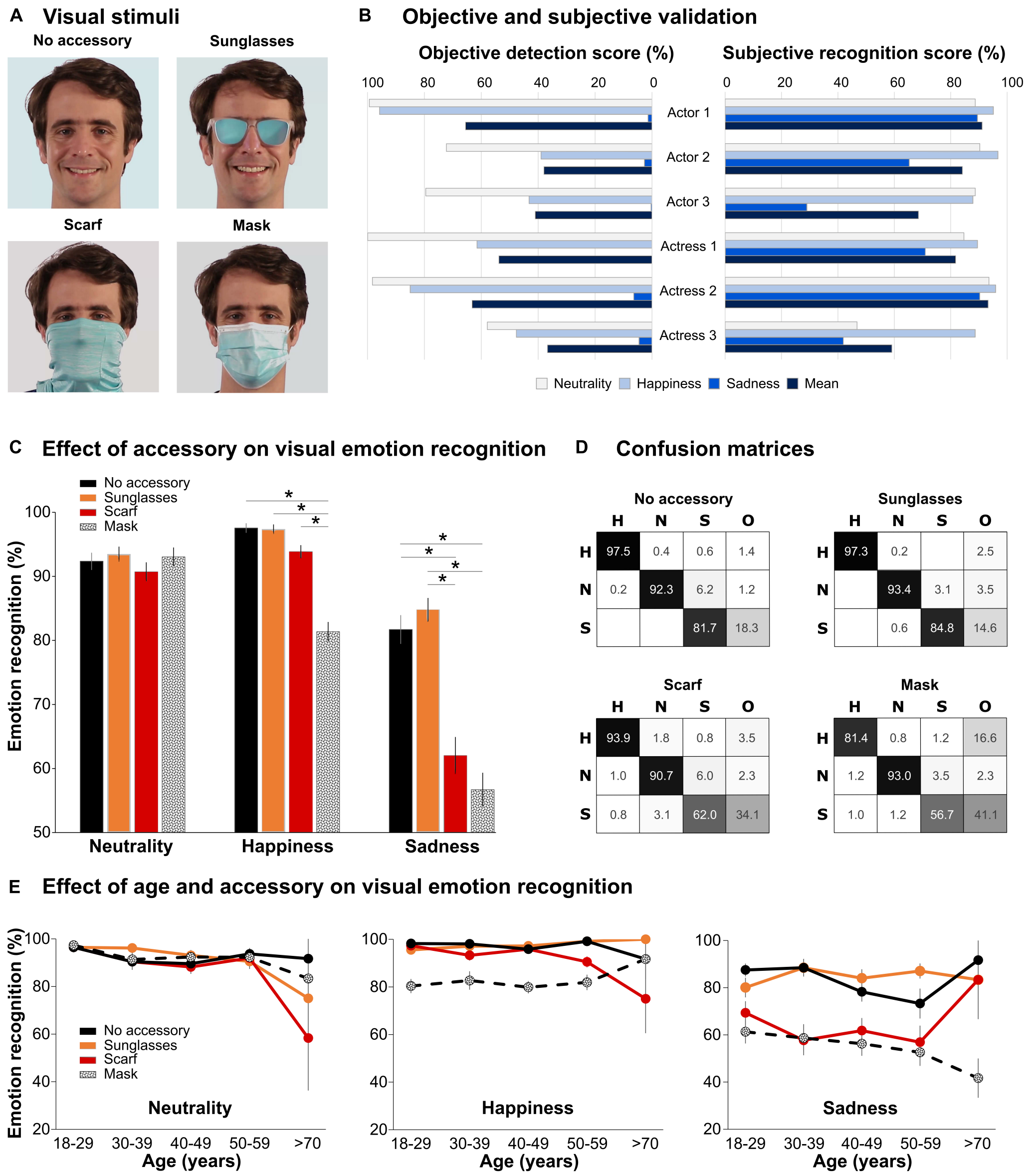

FIGURE 1
Effect of facial accessory on visual emotion recognition. **(A)** Visual stimuli. The four images depict the four accessory conditions (no accessory/sunglasses/scarf/mask) for one actor and one emotion (happiness). The images were extracted from the middle of the video when the emotion was expressed. The color of the background was adjusted, so that the four conditions had the same overall luminosity and colorimetry. **(B)** Objective and subjective validation. Objective detection scores correspond to FaceReader emotion probability converted in % for the six actors and the three emotions in the no accessory condition. Subjective recognition scores correspond to the mean emotion recognition for the same 18 videos by 124 participants. Videos from Actor 3 and Actress 3 were subsequently removed from the analyses, to evaluate the impact of an accessory only on emotions already correctly categorized. Neutrality is represented in light gray, happiness in light blue, sadness in medium blue, and the mean of the three emotions in dark blue. **(C)** Effect of accessory on visual emotion recognition. Histograms represent the mean recognition score (in %, ±standard error) for neutrality (left), happiness (middle), and sadness (right), in the four accessory conditions (black: no accessory, orange: sunglasses, red: scarf, and black-and-white pattern: mask). $^{*}p < 0.05$. **(D)** Confusion matrices. For each accessory condition, the table presents the mean score (in %) of Happiness (H), Neutral (N), Sadness (S), or Other (O) responses (columns) as a function of the actual emotion in the video (lines: H/N/S). The gray level of each cell is proportional to the score (100%: black and 0%: white). **(E)** Effect of age and accessory on visual emotion recognition. Mean recognition score (in %, ±standard error) for neutrality (left), happiness (middle), and sadness (right), in the four accessory conditions (same color code as in panel **C**) for the five age groups.

Set 2 (Figure 2A), four of the previous actors were bare face or wore a surgical mask while articulating either bilabial ([pa]/[ba]) or velar ([ka]/[ga]) syllables and expressing or not an emotion. For each take, three versions were created by removing the visual information for the auditory-only version, the auditory information for the visual-only, and keeping them together for

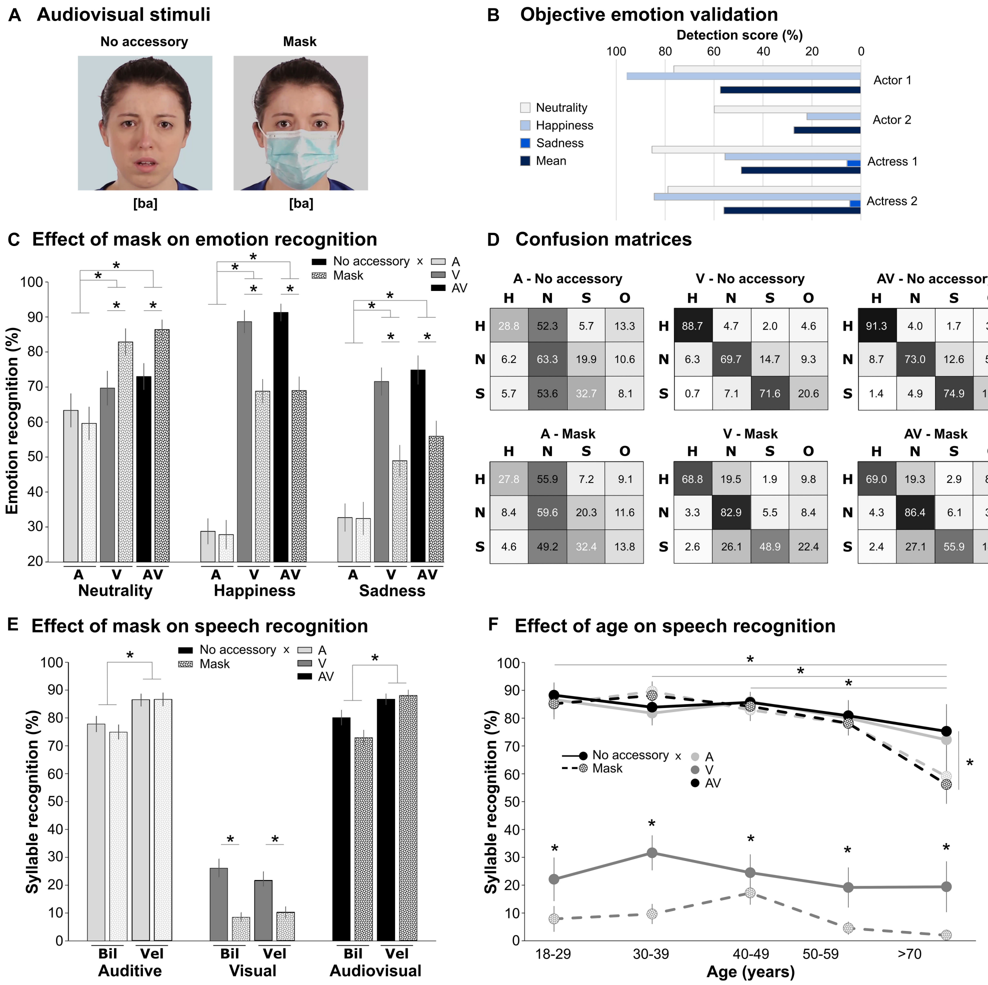

FIGURE 2
Effect of mask on audiovisual emotion and speech recognition. **(A)** Audiovisual stimuli. The two images depict the two accessory conditions (no accessory/mask) for one actress, one emotion (sadness), and one syllable ([ba]). The images were extracted from the middle of the video when the emotion was expressed and the syllable articulated. The color of the background was adjusted, so that the two conditions had the same overall luminosity and colorimetry. **(B)** Objective emotion validation. Detection scores correspond to FaceReader emotion probability converted in % for the four actors and the three emotions in the no accessory condition (pooled across syllables). **(C)** Effect of mask on emotion recognition. Histograms represent the mean recognition score (in %, ±standard error) for neutrality (left), happiness (middle), and sadness (right), in the three modalities (A: auditive, light gray; V: visual, middle gray; and AV: audiovisual, black) in the two accessory conditions (no accessory: full, mask: pattern). *$p < 0.05$. **(D)** Confusion matrices. For each accessory × modality (A/V/AV) condition, the table presents the mean score (in %) of Happiness (H), Neutral (N), Sadness (S), or Other (O) responses (columns) as a function of the actual emotion in the video (lines: H/N/S). The gray level of each cell is proportional to the score (100%: black, 0%: white). **(E)** Effect of mask on speech recognition. Histograms represent the mean recognition score (in %, ± standard error) for auditive (left), visual (middle), and audiovisual (right) modalities, for the bilabial (Bil) and velar (Vel) syllables in the two accessory conditions (same color code as in panel **C**). *$p < 0.05$. **(F)** Effect of age on speech recognition. Syllable recognition score (in %, ±standard error) for the three modalities and the two accessory conditions (same color code as in panel **C**), pooled across syllables, as a function of the age group. *$p < 0.05$.

the audiovisual version. There were 288 videos: 4 actors × 3 modalities × 3 emotions × 4 syllables × 2 accessories. Videos were edited to last 2 s, frame each face identically, and were equated in luminosity and colorimetry (see **Supplementary material**). Soundtracks for each video were normalized in intensity and energy, so no difference in sound intensity was present between masked and unmasked utterances.

Videos without accessories were objectively validated for the intended emotion with FaceReader (FR6; Lewinski et al., 2014). FR6 determines the intensity (on a 0–1 scale) of each specific emotion by estimating the configuration of 20 facial action units (FAU) activated in the expression at each time frame. Intensity score allows emotion categorization. We report the emotion at the maximum of intensity for the intended emotion between 0.5 and 1.5 s, corresponding to the emotion-inducing visual cue. FR6 was calibrated on the neutral video of each actor; then, videos without accessories were analyzed. Objective validation was not possible for the partially occluded videos.

Protocol

The study ran online,[1] with four successive steps: (1) demographic questionnaires; collection of participant's biological sex and age (five categories; 18–29, 30–39, 40–49, 50–69, and more than 70 years old); known developmental disorders (three choices: yes, no, "I don't want to answer"); (2) visual emotion discrimination task; (3) autism quotient (AQ; Lepage et al., 2009; see **Supplementary material**); (4) audiovisual task. Participation was anonymous, and participants could stop at any time. The total duration of the study was about 30 min. This study was approved by the local ethical committee (CER-TP-2021-05-04).

In the visual emotion recognition task, participants were presented a four-alternative forced choice (AFC) (happy, neutral, sad, and other) after each of the 72 videos of Set 1. In the audiovisual task, each participant was shown 96 videos selected randomly from Set 2 (except 5 who saw all the videos). After each video, participants were presented a four-AFC for the emotion recognition (happy, neutral, sadness, and other) and a five-AFC for the syllable recognition ("Ba," "Pa," "Ga," "Ka," and "other").

Participants

Detailed information on the inclusion of participants can be found in **Supplementary material**. For subjective validation of stimuli without accessories, data from 124 participants who completed the task were used to ensure that the posed emotions were correctly recognized by the participants.

For each recognition task independently, participants with performance outside three standard deviations from the mean were considered outliers and were excluded from the analysis.

In the visual emotion recognition task, 133 participants who completed a minimum of 35 trials were considered for analysis. The final sample for statistical analysis included 122 (32 males, 90 females, **Table 1**) participants (11 outliers). These participants provided enough data to obtain a recognition score for each emotion × accessory category.

In the audiovisual task (which includes audio-only, visual-only, and audiovisual stimulation), 43 participants were included. In the audiovisual emotion recognition task, recognition scores were calculated for each emotion × accessory × modality category for 41 participants (two outliers; 14 males, 27 females; **Table 1**); average number of trials per condition was 7 [range: 1 16]. In the audiovisual speech recognition task, recognition scores were calculated for each syllable × accessory × modality category for 41 participants (two outliers; 13 males, 28 females; **Table 1**); average number of trials per condition was 10 [range: 1 24]. In the visual-only condition, participants were deemed to recognize speech through lip reading.

1 https://pavlovia.org/

Statistical analysis

Data were analyzed with a repeated measure ANOVA within the general linear model (GLM) framework using Statistica. Gender was never included due to the strong imbalance in our sample. First, as our population age range was large and age is known to have an emotion-dependent effect on emotion recognition (e.g., West et al., 2012), the GLM included age as a categorical factor (five levels) to make sure data could be pooled across age range. If no effect was found, a final model was run without it. Greenhouse–Geisser correction was applied for data sphericity when needed, and analyses were completed with Bonferroni *post-hoc*.

In the visual emotion recognition task, the GLM included emotion (three levels: happiness, neutral, and sadness) and accessory (four levels: none, sunglasses, scarf, and mask) as within-subject factors. For the audiovisual emotion recognition task, the results were pooled across syllables, and the effects of emotion (three levels: happiness, neutral, and sadness), modality (three levels: audio, audiovisual, and visual), and accessory (two levels: none and surgical mask) were tested. For the audiovisual speech recognition task, the results were pooled across emotions and syllable types (velar vs. bilabial), and the effects of syllable type (two levels: bilabial and velar), modality (three levels: audio, audiovisual, and visual), and accessory (two levels: none and surgical mask) were tested.

Results

Visual emotion recognition task

Validation of the videos without accessory

Categorization (intensity scores converted in %) of neutral expression and happiness by FR6 was much higher than that of sadness (**Figure 1B**) for all actors. Emotion recognition for the 18 videos without accessories ranged from 29 to 96% (**Figure 1B**). Based on this validation, two actors were removed (Actor 3 and Actress 3 on **Figure 1B**) from subsequent analyses as their emotions were not well recognized. Sadness was poorly categorized by FR6, but categorization remained above chance for subjective validation. Emotions in the four actors selected were recognized by more than 60% of the participants, with sadness being less well recognized.

Effect of accessory on emotion recognition

GLM analysis with age as a categorical factor revealed a main effect of emotion [$F(1.5,170.6) = 41.3$, $p < 0.0001$], a main

TABLE 1 Repartition of participants according to age and gender in the three tasks.

Final sample	18–29 years old	30–39 years old	40–49 years old	50–69 years old	>70 years old	Total
Visual emotion discrimination task						
Female	23	20	26	20	1	90
Male	5	6	10	9	2	32
Total	28	26	36	29	3	122
Audiovisual emotion discrimination task						
Female	6	6	8	5	2	27
Male	1	3	3	3	4	14
Total	7	9	11	8	6	41
Audiovisual speech recognition task						
Female	6	6	8	5	3	28
Male	1	3	3	4	2	13
Total	7	9	11	9	5	41

effect of accessory [$F(3,351) = 37.6$, $p < 0.0001$], an emotion by accessory interaction [$F(4.9,567.6) = 12.4$, $p < 0.0001$], and a three-way interaction [$F(19.4,567.6) = 1.75$, $p = 0.015$]. As can be observed in Figure 1C, sadness was overall less recognized than happiness or neutrality ($p < 0.0001$). The mask and the scarf significantly affected emotion recognition ($p < 0.001$ against the two remaining conditions), with worsened performance for the mask ($p < 0.0001$). Specifically, the mask interfered with happiness recognition ($p < 0.0001$) while the scarf did not ($p > 0.9$). Moreover, the mask and scarf interfered with sadness recognition ($p < 0.0001$) but did not differ. Age interacted with emotion and accessory (Figure 1E): Happiness recognition decreased with the mask, except for older participants, who were more affected by the scarf. The recognition of neutral expression was not affected by accessories and decreased with age, in particular for sunglasses and scarf. Sadness recognition was low for both scarf and mask in all age range except in older participants, who were affected by the mask but not the scarf.

Figure 1D shows the confusion matrices for the four accessory conditions. Overall, when participants did not correctly identify the emotion, they chose the response "Other," as if they could not categorize what they saw or that they perceived another emotion not proposed in the choices (like anger or disgust). The neutral condition tended to be categorized more as "Sad" than "Other." Masking the face, in happiness or sadness conditions, increased incertitude, as seen in the augmentation of "Other" responses, rather than making the faces seem more neutral.

Audiovisual task

Objective validation of videos without accessory

The decoding scores of FR6 for the visual-only videos of Set 2 without accessory are presented in Figure 2B (data pooled across syllables). As was observed in the visual task, the categorization of neutral expression and happiness was much higher than that of sadness.

Effect of mask on emotion recognition

When age was included in the GLM, there was an effect of age [$F(4,36) = 2.69$, $p = 0.046$], due to an overall decrease in accuracy with increasing age, but no interaction with other factors. The GLM without age revealed significant main effects of emotion [$F(2,72) = 21.5$, $p < 0.0001$], modality [$F(1.4,49.4) = 115.8$, $p < 0.0001$], accessory [$F(1,36) = 31.7$, $p < 0.0001$], and interactions: (i) emotion by modality [$F(3.1,111.6) = 12.54$, $p < 0.0001$]; (ii) emotion by accessory [$F(2,72) = 19.8$, $p < 0.0001$]; (iii) modality by accessory [$F(1.7,61.6) = 3.8$, $p = 0.034$]; and (iv) three-way interaction [$F(4,144) = 9.06$, $p < 0.0001$]. As can be observed in Figure 2C, accuracy was better for neutral than happiness and sadness recognition, which also differed ($p < 0.01$ for each comparison). Emotion recognition was worse in the auditory modality ($p < 0.0001$ for each comparison) than in the visual and audiovisual conditions which did not differ. Emotion of masked faces was less well recognized than that of non-masked faces, in particular for happiness and sadness ($p < 0.001$). Mask had no effect on the recognition of neutral expression. The emotion by modality interaction revealed that while recognition for happiness and sadness was worse than for neutrality in the auditory modality ($p < 0.0001$ for each comparison), only sadness exhibited worse performances for the visual and audiovisual modalities ($p < 0.02$ for each comparison). For the three-factor interactions, we planned 12 comparisons: We tested the effect of the mask on the nine conditions, and we compared the performance for the visual and audiovisual masked conditions (with the hypothesis that the mask should have less deleterious effect in the audiovisual condition as the auditory input could compensate for masking the mouth). Face mask altered recognition of happiness and sadness ($p < 0.0001$), but improved recognition of neutral expression ($p < 0.002$), in visual and audiovisual conditions. Masking had no effect on emotion recognition in the auditory modality. There was no difference between visual and audiovisual conditions for masked faces.

Figure 2D shows the confusion matrices for the three modalities and two accessories. In the auditory modality, there was a general bias toward the "Neutral" choice, suggesting that syllables did not convey emotional content. In the visual and audiovisual modalities, the mask biased the responses of happiness and sadness toward the "Neutral" choice (whereas it was biased toward "Other" in the visual experiment 3.1.2).

Effect of mask on speech recognition

A GLM with age as a categorical factor revealed main effects of age [$F(4,36) = 7.37$, $p < 0.001$], syllable type [$F(1,36) = 18.8$, $p < 0.001$], modality [$F(1.4,50.4) = 682.8$, $p < 0.001$], accessory [$F(1,36) = 23.5$, $p < 0.001$], and interactions between syllables and accessory [$F(1,36) = 10.01$, $p = 0.003$], syllables and modality [$F(2,72) = 9.86$, $p < 0.001$], and modality and accessory [$F(2,72) = 12.5$, $p < 0.001$]. This later interaction was further characterized by an interaction with age [$F(8,72) = 2.1$, $p = 0.047$]. The main effect of age was driven by participants older than 70 who had syllable recognition accuracy inferior to all others age range ($p < 0.01$), except the 50–69 years old ($p = 0.12$).

Syllable recognition was overall better for velar syllables ([ga]/[ka]), in auditory and audiovisual modalities. Mask impaired syllable recognition (**Figure 2E**), an effect driven by the visual-only condition ($p < 0.001$), due to the absence of any indices to perform the task in visual-only condition with the mask. The syllables by accessory interaction showed that mask only affected the recognition of bilabial syllables ($p < 0.001$; for velar, $p = 0.09$). The syllables by modality interaction arose from velar syllables being better recognized than bilabial syllables in auditory and audiovisual modalities ($p < 0.001$) but not in the visual modality where performance did not differ ($p > 0.5$). To better comprehend the modality by accessory by age interaction, planned comparisons were performed to evaluate the effect of the mask for each modality and each age category (15 comparisons). These showed that while mask had an effect only on the recognition of visual-only syllables in adults below 70, in adults above 70 it also affected the recognition of syllables in the audiovisual condition ($p = 0.009$; $p > 0.77$ for all other age groups) (**Figure 2F**).

Discussion

To study the impact of real-worn masks on social interaction, we recorded videos of actors expressing emotions with natural intensity, with and without real-worn accessories, to create more ecological audiovisual stimuli. Stimuli validation on bare faces showed that sadness was less well recognized than happiness, consistent with other studies (e.g., Carbon, 2020; Noyes et al., 2021). A worsened recognition of sadness compared to happiness could be related to sadness being driven by more subtle cues when actors are asked to perform natural emotions without exaggeration. The results showed an impact of surgical mask on emotion recognition, both in visual only and audiovisual settings, and on syllables perception. The first experiment showed that the effect of surgical mask was specific rather than due to the partial occlusion of the face.

Face masks have emotion-dependent effects on emotion recognition, with impairments observed for happiness (Marini et al., 2021; Grenville and Dwyer, 2022; Levitan et al., 2022), but not for anger or fear (Levitan et al., 2022; Ross and George, 2022). The effects of mask wearing on happiness recognition are relatively consistent across studies whether authors used still photographs of faces or whole bodies (Carbon, 2020; Kastendieck et al., 2021; Marini et al., 2021; Noyes et al., 2021; Grenville and Dwyer, 2022; Levitan et al., 2022; Ross and George, 2022), consistent with the bottom part of the face being more important in the perception of happiness. In agreement with these studies, but unlike Kastendieck et al. (2021) who used videos but with an artificially added mask, we found an effect of mask on happiness recognition. Consistent with our hypothesis, sunglasses did not affect happiness recognition (Noyes et al., 2021), however, neither did the scarf, possibly because it was very tight around the face so that one could see the raised cheeks. The mask-specific alteration of happiness recognition could be linked, not only to masking the mouth, but also to the negative bias of associating mask with infectious disease (Goh et al., 2020) that are not compensated by other information.

Cues important for sadness perception are mostly located in the upper part of the face (Bombari et al., 2013); yet, surprisingly, in our study, sadness recognition was more strongly impacted by wearing a face mask than happiness recognition. This result is both consistent (Carbon, 2020; Marini et al., 2021; Grenville and Dwyer, 2022) and inconsistent with previous studies (Ross and George, 2022). Lack of effect in the latter study possibly reflects compensation from other sources of information, such as body language. In addition, inconsistent with our hypothesis, we had no effect of sunglasses but an effect of scarf on sadness recognition, highlighting that with dynamic stimuli masking the bottom part of the face had a stronger impact on sadness recognition than masking the top part of the face. This could suggest that diagnostic features for faces differ between dynamic and static faces. It would be interesting to compare static and dynamic presentation of masked and non-masked faces. Note that although the mask impaired emotion perception, emotion recognition remained well above chance in our study which could reflect our choice to use an alternative forced-choice task with limited choices. Looking at the confusion matrices, it seems that incorrect answers were due to another emotion being perceived and could suggest that emotion recognition would be more impaired in a free-choice emotion recognition task.

In the audiovisual task, we reported a similar deleterious effect of mask on emotion recognition except for neutral expression, which was improved, due to a response bias toward the neutral choice. Audiovisual stimuli were used to assess whether non-facial information would help in recognizing emotion, as previously shown with body (Ross and George, 2022). However, in our videos, vocal information was not sufficient to compensate for the lost information, possibly because vocal emotions were very poorly recognized.

Perception of speech was affected by mask in particular for the perception of bilabial syllables regardless of modality, suggesting that wearing a mask impairs the production of syllables involving the lips, consistent with reports that face mask alters speech articulatory movements (Gama et al., 2021). However, we did not find a general impact of masks on intelligibility, contrary to Cohn et al. (2021) who reported altered perception for casual and positive speech, possibly due to controlling for intensity across masked and unmasked condition (Gama et al., 2021). In addition, for older participants, the mask impairs the recognition of syllables in the audiovisual condition, suggesting that they rely more on visual cues possibly to compensate potential hearing loss.

Overall, contrary to our expectations, audiovisual presentation did not improve recognition. This could be explained by the major weights of the visual and auditory information for evaluating emotional and speech contents, respectively, and the relatively weak information carried by the non-dominant modality. Conditions were therefore not optimal to produce audiovisual integration and observe a potential compensation of the complementary modality on masked-face perception.

Although our study was the first to test emotion and speech recognition on masked faces in dynamic stimuli, it has several limitations that should be resolved in future study. The study was run online to recruit a representative sample of the general population; however, due to the length of the study and the number of videos to be uploaded, numerous participants stopped the experiment before completing the study. Our sample is therefore inferior to what was expected. There was a large bias toward the participation of female in our study, which could have biased our results as female tends to perform better than male in emotion recognition tasks (Collignon et al., 2010; Kret and De Gelder, 2012b; Lambrecht et al., 2014; Abbruzzese et al., 2019). The audiovisual stimuli and the real-worn mask allowed us to be in a more ecological environment; nonetheless, faces and voices are rarely presented as were done here and often other cues are present at the same time, suggesting that in real life, other information may help deciphering the emotion expressed by individual. Nonetheless, the results for speech perception remain important and demonstrate that masking the face as a stronger impact on older people.

Conclusion

Using a new controlled ecological audiovisual video database, we demonstrated that real-worn masks impact social interaction, including both emotion and speech perception and that this effect reflects a physical effect due to loosing information, and possibly a cognitive bias, due to the COVID-19 pandemic. Nonetheless, recognition of speech and emotion remained well above chance, suggesting the effect is less pronounced than originally thought.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Comité d'Éthique pour la Recherche sur la Personne, Université de Tours et de Poitiers (Agreement CER-TP-2021-05-04). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RJ created the database, including filming and editing the videos. NA-H, ML, and CW contributed equally to all other aspects of the study. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnins.2022.982899/full#supplementary-material

References

Abbruzzese, L., Magnani, N., Robertson, I. H., and Mancuso, M. (2019). Age and gender differences in emotion recognition. *Front. Psychol.* 10:2371. doi: 10.3389/fpsyg.2019.02371

Aguillon-Hernandez, N., Mofid, Y., Latinus, M., Roché, L., Bufo, M. R., Lemaire, M., et al. (2020). The pupil : A window on social automatic processing in autism spectrum disorder children. *J. Child Psychol. Psychiatry* 61, 768–778. doi: 10.1111/jcpp.13170

Blais, C., Roy, C., Fiset, D., Arguin, M., and Gosselin, F. (2012). The eyes are not the window to basic emotions. *Neuropsychologia* 50, 2830–2838. doi: 10.1016/j.neuropsychologia.2012.08.010

Bombari, D., Schmid, P. C., Schmid Mast, M., Birri, S., Mast, F. W., and Lobmaier, J. S. (2013). Emotion recognition : The role of featural and configural face information. *Q. J. Exp. Psychol.* 66, 2426–2442. doi: 10.1080/17470218.2013.789065

Bould, E., and Morris, N. (2008). Role of motion signals in recognizing subtle facial expressions of emotion. *Br. J. Psychol.* 99, 167–189. doi: 10.1348/000712607X206702

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Cohn, M., Pycha, A., and Zellou, G. (2021). Intelligibility of face-masked speech depends on speaking style : Comparing casual, clear, and emotional speech. *Cognition* 210:104570. doi: 10.1016/j.cognition.2020.104570

Collignon, O., Girard, S., Gosselin, F., Saint-Amour, D., Lepore, F., and Lassonde, M. (2010). Women process multisensory emotion expressions more efficiently than men. *Neuropsychologia* 48, 220–225. doi: 10.1016/j.neuropsychologia.2009.09.007

de Boer, M. J., Jürgens, T., Cornelissen, F. W., and Başkent, D. (2021). Degraded visual and auditory input individually impair audiovisual emotion recognition from speech-like stimuli, but no evidence for an exacerbated effect from combined degradation. *Vis. Res.* 180, 51–62. doi: 10.1016/j.visres.2020.12.002

Fischer, A. H., Gillebaart, M., Rotteveel, M., Becker, D., and Vliek, M. (2012). Veiled emotions : The effect of covered faces on emotion perception and attitudes. *Soc. Psychol. Pers. Sci.* 3, 266–273. doi: 10.1177/1948550611418534

Fitousi, D., Rotschild, N., Pnini, C., and Azizi, O. (2021). Understanding the impact of face masks on the processing of facial identity, emotion, age, and gender. *Front. Psychol.* 12:743793. doi: 10.3389/fpsyg.2021.743793

Gama, R., Castro, M. E., van Lith-Bijl, J. T., and Desuter, G. (2021). Does the wearing of masks change voice and speech parameters? *Eur. Arch. Oto Rhino Laryngol.* 279, 1701–1708.

Goh, Y., Tan, B. Y. Q., Bhartendu, C., Ong, J. J. Y., and Sharma, V. K. (2020). The face mask : How a real protection becomes a psychological symbol during Covid-19? *Brain Behav. Immun.* 88, 1–5. doi: 10.1016/j.bbi.2020.05.060

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking emotions : Face masks impair how we read emotions. *Front. Psychol.* 12:1541. doi: 10.3389/fpsyg.2021.669432

Grenville, E., and Dwyer, D. M. (2022). Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion. *Cogn. Res. Princ. Implic.* 7:15. doi: 10.1186/s41235-022-00366-w

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Kastendieck, T., Zillmer, S., and Hess, U. (2021). (Un)mask yourself ! Effects of face masks on facial mimicry and emotion perception during the COVID-19 pandemic. *Cogn. Emot.* 36, 59–69. doi: 10.1080/02699931.2021.1950639

Kret, M. E., and de Gelder, B. (2012a). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Kret, M. E., and De Gelder, B. (2012b). A review on sex differences in processing emotional signals. *Neuropsychologia* 50, 1211–1221. doi: 10.1016/j.neuropsychologia.2011.12.022

Lambrecht, L., Kreifelts, B., and Wildgruber, D. (2014). Gender differences in emotion recognition : Impact of sensory modality and emotional category. *Cogn. Emot.* 28, 452–469. doi: 10.1080/02699931.2013.837378

Lepage, J.-F., Lortie, M., Taschereau-Dumouchel, V., and Théoret, H. (2009). Validation of French-Canadian versions of the empathy quotient and autism spectrum quotient. *Can. J. Behav. Sci.* 41:272.

Levitan, C. A., Rusk, I., Jonas-Delson, D., Lou, H., Kuzniar, L., Davidson, G., et al. (2022). Mask wearing affects emotion perception. *Iperception* 13:20416695221107390. doi: 10.1177/20416695221107391

Lewinski, P., den Uyl, T. M., and Butler, C. (2014). Automated facial coding : Validation of basic emotions and FACS AUs in FaceReader. *J. Neurosci. Psychol. Econ.* 7:227.

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Maurer, D., Grand, R. L., and Mondloch, C. J. (2002). The many faces of configural processing. *Trends Cogn. Sci.* 6, 255–260. doi: 10.1016/S1364-6613(02)01903-4

Meaux, E., and Vuilleumier, P. (2016). Facing mixed emotions : Analytic and holistic perception of facial emotion expressions engages separate brain networks. *Neuroimage* 141, 154–173. doi: 10.1016/j.neuroimage.2016.07.004

Nguyen, D. D., McCabe, P., Thomas, D., Purcell, A., Doble, M., Novakovic, D., et al. (2021). Acoustic voice characteristics with and without wearing a facemask. *Sci. Rep.* 11:5651. doi: 10.1038/s41598-021-85130-8

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Roberson, D., Kikutani, M., Döge, P., Whitaker, L., and Majid, A. (2012). Shades of emotion : What the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition* 125, 195–206.

Ross, P., and George, E. (2022). Are face masks a problem for emotion recognition? Not when the whole body is visible. *Front. Neurosci.* 16:915927. doi: 10.3389/fnins.2022.915927

Saunders, G. H., Jackson, I. R., and Visram, A. S. (2021). Impacts of face coverings on communication : An indirect impact of COVID-19. *Int. J. Audiol.* 60, 495–506. doi: 10.1080/14992027.2020.1851401

West, J. T., Horning, S. M., Klebe, K. J., Foster, S. M., Cornwell, R. E., Perrett, D., et al. (2012). Age effects on emotion recognition in facial displays: from 20 to 89 years of age. *Exp. Aging Res.* 38, 146–168. doi: 10.1080/0361073X.2012.659997

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Emotional context can reduce the negative impact of face masks on inferring emotions

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While face masks prevent the spread of disease, they occlude lower face parts and thus impair facial emotion recognition. Since emotions are often also contextually situated, it remains unknown whether providing a descriptive emotional context alongside the facial emotion may reduce some of the negative impact of facial occlusion on emotional communication. To address this question, here we examined how emotional inferences were affected by facial occlusion and the availability of emotional context. Participants were presented with happy or sad emotional faces who were either fully visible or partially obstructed by an opaque surgical mask. The faces were shown either within an emotionally congruent (e.g., "Her cat was found/lost yesterday afternoon") or neutral ("Get ready to see the next person") context. Participants were asked to infer the emotional states of the protagonists by rating their emotional intensity and valence. Facial occlusion by masks impacted the ratings, such that protagonists were judged to feel less intense and more neutral emotions when they wore masks relative to when their face was fully visible. Importantly, this negative impact of visual occlusion by mask was reduced but not fully eliminated when the faces were presented within a congruent emotional context. Thus, visual occlusion of facial emotions impairs understanding of emotions, with this negative effect of face masks partially mitigated by the availability of a larger emotional context.

KEYWORDS

lower face occlusion, face masks, emotion recognition, emotional inference, emotional context, face feature occlusion

Introduction

With the onset of the COVID-19 pandemic, the world saw an unprecedented but necessary widespread adoption of face masks. While masks provide much needed protection again virus spread (Eikenberry et al., 2020; Leung et al., 2020; Prather et al., 2020), they also present challenges to visual social communication as they obstruct approximately 60–70% of the face parts needed for socioemotional messaging (e.g., Carbon, 2020; Mheidly et al., 2020; Molnar-Szakacs et al., 2021 for reviews). Faces are some of most important social stimuli we encounter, and humans readily utilize visible cues from faces to recognize emotions in others (Hugenberg and Wilson, 2013). It has long been demonstrated that facial expressions provide a quick and easy way to extract information about others' emotional states (e.g., Ekman, 1999), with the ability to read these expressions associated with increased levels of several facets of overall social functioning (e.g., Leppänen and Hietanen, 2001; Addington et al., 2006) including prosocial behavior (Marsh et al., 2007), social approach (Williams et al., 2014), and empathy (Besel and Yuille, 2010).

Many social judgments are made from facial cues (e.g., Klapper et al., 2016). It is thus unsurprising that face masks have been shown to impact many of these judgments, including reducing perceived closeness (Grundmann et al., 2021), increasing perceived attractiveness (Hies and Lewis, 2022; Parada-Fernández et al., 2022) and either increasing (Cartaud et al., 2020; but see Grundmann et al., 2021) or decreasing (Biermann et al., 2021; Gabrieli and Esposito, 2021) perceived trustworthiness. The alterations in such second-order trait perception likely stem from the obstruction of the visual information from the lower face cues needed for basic processes that inform these judgments, such as emotion recognition (Carbon, 2020; Grundmann et al., 2021; Carbon and Serrano, 2021; Williams et al., 2021; Grenville and Dwyer, 2022; Kim et al., 2022; McCrackin et al., 2022a; Parada-Fernández et al., 2022). Indeed, emotion recognition performance for faces obstructed by face masks can decline from 10 to 45% depending on the emotional expression (Carbon, 2020; McCrackin et al., 2022a). That is, recognition of emotional expressions thought to have particularly diagnostic lower face features like disgust and anger (e.g., Ekman, 1999; Smith et al., 2005; Blais et al., 2012; Kret and de Gelder, 2012; Wegrzyn et al., 2017) is the most impacted by lower face occlusion while recognition of expressions with diagnostic upper face regions like fear and surprise is least impacted by lower face occlusion (Carbon, 2020; Carbon and Serrano, 2021; Williams et al., 2021; Grenville and Dwyer, 2022; Kim et al., 2022; McCrackin et al., 2022a).

While the impact of masks on basic emotion recognition is clear (Carbon, 2020; Grundmann et al., 2021; Carbon and Serrano, 2021; Williams et al., 2021; Grenville and Dwyer, 2022; Kim et al., 2022; McCrackin et al., 2022a), recognition of emotional expressions is typically situated within a broader emotional context (Wieser and Brosch, 2012). For example, one might perceive a smile alongside a joke being told or hearing good news being shared. In other words, making emotional inferences requires not only emotional information from faces (Baron-Cohen and Cross, 1992; Clark et al., 2008; Mier et al., 2010; Decety et al., 2015; Stewart et al., 2019) but also contextual information like emotional prosody, body language, prior knowledge, emotional understanding, and/or emotional context (Wieser and Brosch, 2012 for a review).

Here we sought to examine the role of emotional context in making emotional inferences from faces occluded by face masks. Can availability of emotional context ameliorate the negative impact of facial occlusion on emotional communication? To address this question, we asked participants to judge the emotions of protagonists who displayed happy and sad facial expressions and either wore a surgical mask or had their face visually unobstructed. Critically, on half of the trials, the protagonists were presented within a congruent emotional context—a written sentence describing a happy or sad event happening to the protagonist. In the other half of trials, the protagonists were presented within a neutral context—a written sentence informing participants to get ready for the next trial. On each trial, participants rated the intensity and valence of the protagonist's emotion. Intensity refers to degree of arousal, while valence refers to the degree of pleasantness. The Circumplex theory of emotion (Russell, 1980) suggests that intensity and valence constitute two unique dimensions of affective experience. There is both behavioral and neural evidence to suggest that these dimensions can be dissociated (e.g., Anderson and Sobel, 2003; Kensinger and Corkin, 2004; Colibazzi et al., 2010). For example, strong positive valence can either be paired with high intensity in the experience of happiness or low intensity in the experience of serenity. Thus we decided to examine how facial obstruction by face masks impacted both aspects of affective perception. We also reasoned that using ratings of valence and intensity as in our previous work (see also McCrackin and Itier, 2021; McCrackin et al., 2022a) would avoid potential ceiling effects that may occur from the utilization of forced choice paradigms typically used in emotion recognition given that here we did not only present facial emotional expressions, but also emotional sentences with clear emotional content.

Following from past work (e.g., McCrackin et al., 2022b), we expected to observe diminished (i.e., more neutral) ratings of the protagonists' emotions when they wore masks. However, if this negative effect of facial obstruction was modulated by the availability of emotional context, we expected to find higher emotional ratings for faces wearing masks in conditions in which congruent context was provided relative to conditions in which no context was provided. Our data supported these predictions.

Methods

This study was pre-registered.[1] Anonymized and summarized data are available at https://osf.io/9bmr3/?view_only=e0871f7add364e378eccd9920f60d98b.

1 https://osf.io/hm59u

Participants

Seventy undergraduate students participated for course credit and were included in the analysis (66 female, 3 male, 1 other; Mean age: 20.41, *SE* = 0.13).[2] Sample size was pre-registered and determined with a conservative power analysis based on our previous work with face masks and emotion recognition (McCrackin et al., 2022a) and affective theory of mind (McCrackin et al., 2022b). Participants provided informed consent and the McGill University research ethics board approved the study.

Apparatus and stimuli

The experiment took place online *via* Testable[3] with stimuli scaled to fit each participant's personal computer screen. Sample face stimuli are shown in **Figure 1A**. Images of happy and sad face stimuli were obtained for 20 male and 20 female identities from the FACES (Ebner et al., 2010) and Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998) databases, which have independently validated that these images depict facial expressions with high recognizability (Goeleven et al., 2008; Ebner et al., 2010).[4] For the Mask condition, a photograph of a surgical mask was applied to each face using Adobe Photoshop CS6 and scaled such that the mask spanned the lower edge of the chin, the bridge of the nose, and the edges of the cheeks.

As depicted in **Figure 1B**, each face stimulus was preceded by a sentence. In the Context condition, the sentence described a face expression within a congruent happy or sad emotional event happening to the protagonists (e.g., "Her pet cat was *found/lost* yesterday afternoon"). Male and female happy and sad variations of 12 emotional sentence themes from McCrackin and Itier (2021) were presented,[5] as they have repeatedly been demonstrated to elicit the expected emotional responses (McCrackin and Itier, 2021; McCrackin et al., 2022b). In the No Context condition, the sentence "Get ready for the next person to appear" was displayed. This sentence had the same number of syllables as the emotional sentences and similarly referenced the protagonist but did not provide any emotional information.

Design and procedure

The study was a repeated measures design with three factors—Context (2; Context; No Context), Emotion (2; Happy, Sad), and Mask (2; Mask, No Mask). Context manipulated whether an emotional sentence (Context) or neutral sentence (No Context) preceded the presentation of a protagonist's emotional face. This variable was blocked, such that half of the testing blocks (i.e., 4) provided emotional context (Context blocks) and half did not (No Context blocks), with the block order and trials within the blocks randomized. The factor of Emotion manipulated whether the face depicted a Happy or Sad facial expression. Facial expression and emotional context were congruent during the Context condition such that happy context sentences were always paired with happy expressions and sad context sentences were paired with sad expressions.[6] The Mask factor manipulated whether the face wore a face mask (Mask) or not (No Mask).

Manipulating these three factors yielded 8 experimental conditions. Each condition was sampled 24 times for a total of 192 trials divided across 8 testing blocks. The same face identities were presented in the Context and No Context blocks so that the impact of emotional context could be examined without changing any other variables (i.e., participants saw the same face image once with context and once without context). All conditions were equiprobable and presented using a pseudorandom sequence.

Figure 1B illustrates a typical trial. Participants were first shown either an emotional context sentence (Context condition) or a neutral sentence (No Context condition) for 4,000 ms. A 200 ms fixation cross preceded a presentation of the Happy or Sad emotional face either wearing a mask (Mask) or not wearing a mask (No Mask) for 2,000 ms. After the image presentation, participants were asked to use a 9-point Likert scale to rate the protagonists' *(i)* emotional intensity ranging from 0/very un-intense to 9/very intense, and *(ii)* emotional valence from

2 Data quality was very high. No participants met our pre-registered exclusions criteria of having more than 20% data loss due to anticipations (responses faster than 500 ms) or not providing responses. Data from 71 participants was originally collected, but one participant was removed from analysis because there was a record of them completing the study multiple times. In the final sample, trial completion was high, with the average number of valence and arousal responses completed being 191.79/192 (*SD* = 0.70) and 192.93/192 (*SD* = 0.31), respectively. All participants had normal or corrected-to-normal vision, English fluency, no diagnosis of mental illness, and no previous head trauma.

3 https://www.testable.org/

4 Stimuli Identities: Males- KM08, KM11, KM31, M13, M25, M16, M37, M49, M57, M62, M66, M72, M81, M89, M105, M99, M109, M114, M119, M123. Females—F48, F54, F63, F69, F71, F85, F90, F98, F101, F106, F115, F125, F132, F134, F140, F162, F171, F163, F177, F182.

5 The following sentence themes were selected from the list of 25 starred themes in McCrackin and Itier (2021, **Table 1**), with Theme 1 referencing the first starred sentence: Theme 13, Theme 14, Theme 15, Theme 16, Theme 17, Theme 18, Theme 20, Theme 21, Theme 22, Theme 23, Theme 24, Theme 25.

6 We had examined how a neutral emotion condition (using both neutral sentences and facial expression) influences affective judgments in our recent work assessing how face covering with opaque vs. transparent face masks impacted affective theory of mind and empathy ratings (McCrackin et al., 2022b). In this study, we observed that the neutral emotion condition generated data which fell in between happy and sad conditions (as it would be expected), with ratings close a perfect neutral score of 5 on the Likert scale when faces were covered by a transparent mask. Given this result, and to maximize understanding the differences in emotional processing for positively and negatively valanced emotions, in the present study we examined only the positive and negative emotional conditions.

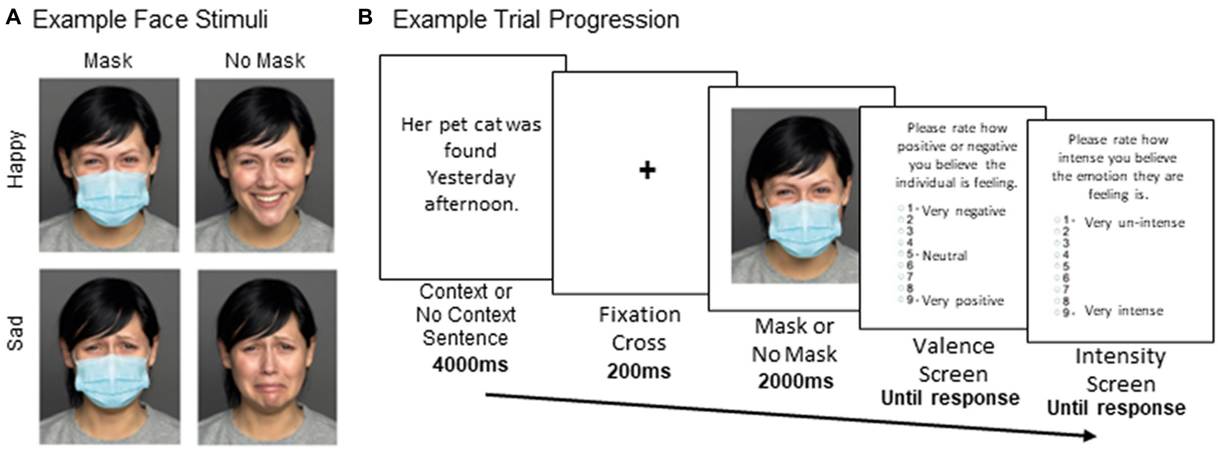

FIGURE 1
(A) Example face stimuli. **(B)** Example trial progression. In the Context condition, an emotional sentence congruent with the face emotion (either happy or sad) was provided at the start. In the No context condition, the sentence "Get ready for the next person to appear" was presented instead. Following the emotional face image, participants rated the intensity and valence of the protagonist's emotional state using two separate scales (valence and intensity).

0/very negative to 9/very positive on separate screens and were given unlimited time to make each response. These two rating scales were designed to probe the affective dimensions of valence (pleasure) and arousal (intensity) theorized by the Circumplex model of emotion (Russell, 1980) to represent dissociated components of the emotional experience.

Results

Mean ratings of the protagonists' emotional intensity and valence were calculated for each participant. Then, two separate repeated measures ANOVAs were run on each dependant variable (i.e., intensity and valence) with Context (Context, No Context), Emotion (Happy, Sad), and Mask (Mask, No mask) included as factors. Follow-up two-tailed paired-test tests were performed where required, with Bonferroni correction applied to the nominal $\alpha = 0.05$ level.

To remind, we hypothesized that if context contributes significantly to emotional understanding, availability of a congruent emotional context should provide mitigating effect under conditions in which visual facial cues are unavailable due to facial obstruction by mask.

Intensity

Confirming the efficacy of our context manipulation, a main effect of Context indicated that intensity ratings were overall higher when a protagonist was presented within an emotional context relative to no context [$F(1, 69) = 48.92$, $MSE = 0.60$, $p = 1.36 \times 10^{-9}$, $\eta_p{}^2 = 0.42$]. As depicted in **Figure 2A**, a Context × Emotion interaction indicated that availability of an emotional context increased intensity ratings for happy emotions more than for sad ones [$F(1, 69) = 7.87$, $MSE = 0.18$, $p < 0.007$, $\eta_p{}^2 = 0.10$], although the effect was significant for both happy [$t(69) = 8.13$, $p = 1.14 \times 10^{-11}$, $SE = 0.080$ $d = 0.97$] and sad trials [$t(69) = 4.46$, $p = 3.1 \times 10^{-5}$, $SE = 0.069$, $d = 0.53$].

Replicating previous work indicating that facial obstruction by masks alters emotional inferences (McCrackin et al., 2022b), a main effect of Mask indicated that faces wearing masks were judged to feel less intense emotion than those not wearing masks [$F(1, 69) = 84.87$, $MSE = 0.73$, $p = 1.23 \times 10^{-13}$, $\eta_p{}^2 = 0.55$]. As shown in **Figure 2B**, a Mask x Emotion interaction indicated that this reduction in perceived emotional intensity for faces wearing masks was also larger for happy than for sad emotions [$F(1, 69) = 38.30$, $MSE = 0.15$, $p = 3.80 \times 10^{-8}$, $\eta_p{}^2 = 0.36$], although wearing masks reduced emotional intensity ratings for both happy [$t(69) = -10.35$, $p = 1.09 \times 10^{-15}$, $SE = 0.083$, $d = -1.24$] and sad emotions [$t(69) = -6.18$, $p = 3.92 \times 10^{-8}$, $SE = 0.074$, $d = -0.74$].

Finally, we predicted that adding emotional context may be able to reduce some of the negative impact of facial occlusion by masks on emotional inferences. Indeed, and as depicted in **Figure 2C**, there was a significant Context × Mask interaction [$F(1, 69) = 16.39$, $MSE = 0.065$, $p = 1.33 \times 10^{-4}$, $\eta_p{}^2 = 0.19$]. While there was an effect of mask for both Context [$t(69) = -7.93$, $p = 2.68 \times 10^{-11}$, $SE = 0.072$, $d = -0.95$] and No Context conditions [$t(69) = 9.67$, $p = 1.81 \times 10^{-14}$, $SE = 0.072$, $d = -1.16$], the effect of visual occlusion by Masks (computed as Intensity rating without masks—Intensity rating with masks) was reduced by approximately 23% when Context was provided [$t(69) = -4.05$, $p = 1.33 \times 10^{-4}$, $SE = 0.043$, $d = -0.48$], as depicted in **Figure 2D**. The three-way interaction

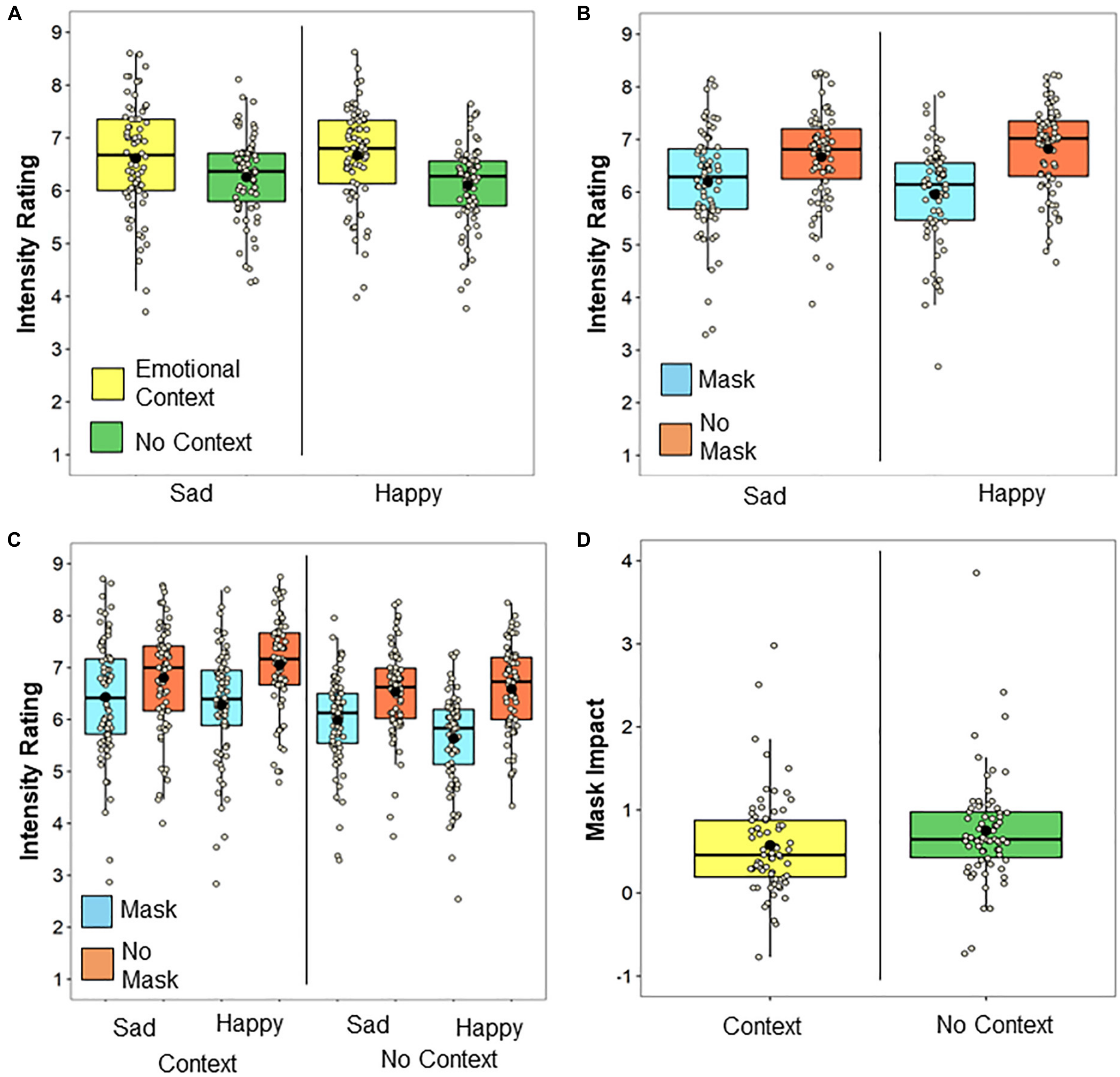

FIGURE 2
Intensity ratings. The mean and median for each condition are indicated with a black dot and solid line, respectively, and each participants' data point is plotted. Impact of **(A)** emotional context and **(B)** mask on intensity ratings for each emotion. **(C)** The impact of masks on intensity ratings as a function of Emotion and Context. **(D)** The overall mask impact (unmasked intensity—masked intensity ratings) with and without context. Note that the rating of 1 represents the lowest emotional intensity.

between Context, Emotion, and Mask was not significant [$F(1, 69) = 0.005$, MSE = 0.08, $p = 0.94$, $\eta_p^2 < 0.001$].

Valence

Similarly to intensity, and confirming the efficacy of the emotional manipulation, a main effect of Emotion valence indicated that protagonists were judged to feel more positive in the happy emotional condition compared to the sad emotional condition [$F(1, 69) = 1537.32$, $MSE = 1.97$, $p = 6.75 \times 10^{-49}$, $\eta_p^2 = 0.96$]. A main effect of Mask reflected that protagonists were also judged to feel more positive when their face was visually unobstructed as opposed to when they were wearing masks [$F(1, 69) = 33.29$, $MSE = 0.11$, $p = 2.06 \times 10^{-7}$, $\eta_p^2 = 0.33$], although this was qualified by a Mask by Emotion interaction discussed below.

As shown in Figure 3A, significant Context x Emotion interaction indicated that availability of emotional context led to heightened assumptions of the individual feeling the inferred emotion [$F(1, 69) = 94.41$, $MSE = 0.26$, $p = 1.51 \times 10^{-14}$, $\eta_p^2 = 0.58$]. That is, availability of an emotional context

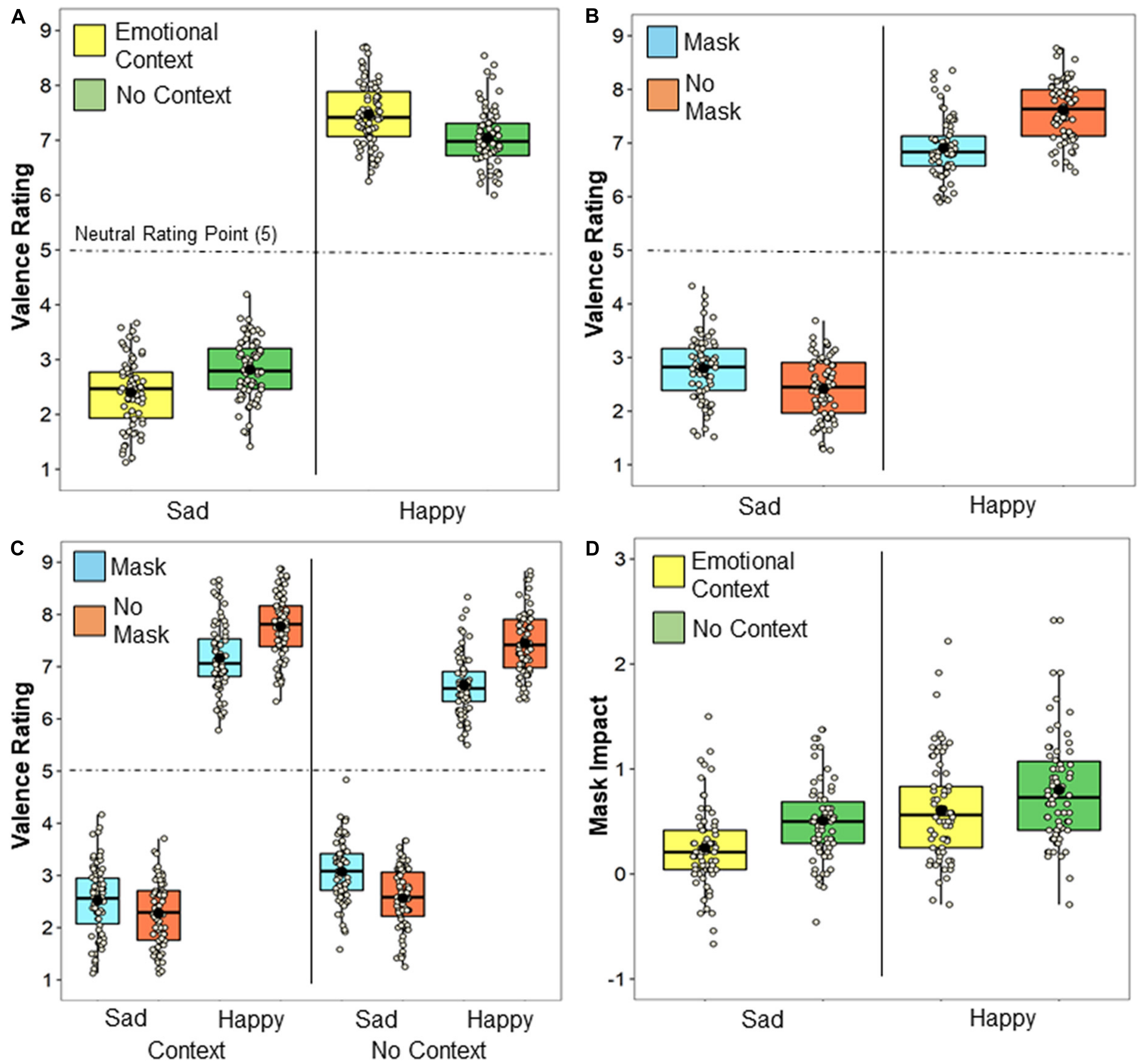

FIGURE 3
Valence ratings. The mean and median for each condition are indicated with a black dot and solid line, respectively, and each participants' data point is plotted. Impact of **(A)** emotional context and **(B)** mask on valence ratings for each emotion. **(C)** The impact of masks on valence ratings as a function of emotion and context. **(D)** The overall impact of masks (unmasked valence—masked valence ratings for happy emotion, and masked valence—unmasked valence for sad emotion) for positive happy and sad negative emotions as a function of context. The neutral valence point (rating 5) is indicated by the dotted line.

increased valence ratings for happy trials ($p < 0.001$) and decreased valence ratings for sad trials ($p < 0.001$), with the magnitude of this effect no different between the happy and sad emotion conditions ($p = 0.86$).

Further, as depicted in Figure 3B, a Mask x Emotion interaction [$F(1, 69) = 41.06$, $MSE = 0.22$, $p = 2.50 \times 10^{-21}$, $\eta_p{}^2 = 0.73$] indicated that individuals wearing masks were rated as feeling more neutral emotions than those not wearing masks, replicating our previous work (McCrackin et al., 2022b). For happy trials, protagonists wearing masks were rated with lower valence ratings [$t(69) = -12.77$, $p = 7.58 \times 10^{-20}$, $SE = 0.055$, $d = -0.1.53$], while for sad trials, they were rated with higher valence ratings [$t(69) = 9.18$, $p = 1.43 \times 10^{-13}$, $SE = 0.042$, $d = 1.10$]. The impact of masks on valence ratings was larger for happy trials than for sad trials [$t(69) = 5.77$, $p = 2.06 \times 10^{-7}$, $SE = 0.057$, $d = 0.69$].

Finally, as illustrated in Figure 3C, there was also a three-way interaction between Context, Emotion, and Mask [$F(1, 69) = 48.74$, $MSE = 0.04$, $p = 1.44 \times 10^{-9}$, $\eta_p{}^2 = 0.41$]. As shown, this interaction was driven by the availability of emotional context reducing the impact of masks on valence ratings during both sad [$t(69) = -9.26$, $p = 1.27 \times 10^{-13}$, $SE = 0.045$, $d = -1.11$]

and happy [$t(69) = 8.76$, $p = 8.30 \times 10^{-13}$, $SE = 0.048$, $d = 1.05$] emotions, with a similar magnitude [$t(69) = 0.17$, $p = 0.86$, $SE = 0.036$, $d = 0.02$]. Proportionately, availability of context reduced the negative effect of facial occlusion on valence ratings, plotted in **Figure 3D**, by 51% for sad emotions and by 24% for happy emotions.

To summarize, providing emotional context was overall associated with emotional judgments of protagonists feeling more intense emotions and stronger emotional valence. When protagonists wore face masks they were judged as feeling less intense and weaker emotional valence, particularly for happy emotions. The availability of emotional context significantly reduced the negative impact of face masks on both ratings of intensity and valence, with the magnitude of this reduction ranging from 23% up to 51%.

Discussion

Lower face occlusion with face masks has been shown to impair our ability to recognize facial emotional expressions (Carbon, 2020; Grundmann et al., 2021; Carbon and Serrano, 2021; Williams et al., 2021; Grenville and Dwyer, 2022; Kim et al., 2022; McCrackin et al., 2022a), prompting concerns about the effectiveness of social interactions in masked situations (Mheidly et al., 2020; Molnar-Szakacs et al., 2021). However, during real life social interactions, emotional expressions are typically experienced within a broader emotional context that might compensate for the lack of lower face cues (Wieser and Brosch, 2012). Thus, it is important to consider how emotional context may affect emotional processing under conditions when visual emotional information from faces may not be available.

To investigate this question, we presented participants with images of emotional faces who either wore masks or had their faces visually unobstructed. Critically, the protagonists were presented within either an emotional or neutral context. Participants were asked to rate the emotional state of each protagonist. The data indicated overall reduced emotional processing from faces wearing masks. Availability of emotional context reduced, but did not fully reverse, this negative impact of facial occlusion. Next, we discuss two points relating to these data.

First, replicating and extending existing reports (Carbon, 2020 for a review) we found an impact of face occlusion by masks on emotional inferences, both when emotional context was available and when it was not available. When protagonists wore masks they were judged as feeling more neutral and less intense emotion. This finding dovetails with recent work from both emotion recognition (Carbon, 2020; Grundmann et al., 2021; Carbon and Serrano, 2021; Williams et al., 2021; Grenville and Dwyer, 2022; Kim et al., 2022; McCrackin et al., 2022a) and emotional valence and intensity paradigms (McCrackin et al., 2022b) to suggest that face occlusion by masks significantly impacts not only basic emotion recognition but also judgments of emotional states that integrate both emotional expressions and contextual information.

Of note here is our finding that face covering by masks seemed to impact happy emotional inferences more than sad ones. We recently found a similar asymmetry for understanding happy emotions to be more impacted than understanding sad emotions when we asked participants to both infer and share emotions with protagonists wearing face masks (McCrackin et al., 2022b). One explanation for this finding is that face masks impact the perception of happy expressions more than they impair the perception of sad ones. Consequently, this basic emotion perception impairment may exert a larger downstream effect on happy emotional inferences. While some recent studies have reported greater impact in recognizing sad relative to happy expressions from masked faces (Carbon, 2020; Williams et al., 2021; Kim et al., 2022; McCrackin et al., 2022a), it is important to highlight that these studies have mainly examined overall emotion recognition accuracy (i.e., percent correct identifications) and happy facial expressions are well known to be the easiest emotion to recognize (i.e., the so-called happy superiority effect in emotion recognition; e.g., Neath, 2012; for a review; Svard et al., 2012; Švegar et al., 2013). It is possible that happy expressions are still easily recognized from faces wearing masks due to ceiling effects, but the perceived intensity and valence of those happy expressions remain more strongly impacted than perceived intensity and valence of sad expressions. In line with this point, our data also suggest that perception of happy facial expressions was impacted more by lower face occlusion than the perception of sad facial expressions. This is likely because the diagnostic smile is fully covered by the face mask, while the eyes remain unobstructed as a clear diagnostic feature for sadness (e.g., Ekman, 1999; Smith et al., 2005; Blais et al., 2012; Kret and de Gelder, 2012; Wegrzyn et al., 2017). Future studies are needed to further understand the links between different facets of emotional inferences under conditions in which facial cues may not be readily available.

Second, we also found that availability of an emotional context reduced the negative impact of facial occlusion by masks on ratings of both happy and sad emotional states. That is, masked individuals received closer ratings to the unmasked individuals when their images were paired with a congruent emotional context as opposed to when their images were paired with a neutral context. Thus, while contextual information was not necessary for understanding the general emotional state, it modulated the extent to which the inferred emotional state was impacted by visual occlusion of face parts. The reduction of the mask impact ranged from 23% for intensity ratings, and 51% for sad valence ratings, to 24% for happy valence ratings. As such, this suggests that providing contextual statements during social interactions while protagonists wear masks may provide a relatively simple way in which the impact of facial occlusion by masks can be reduced.

There are a few points that warrant further investigation. First, our study used static images with photoshopped masks. Since dynamicity typically facilitates emotion recognition (e.g., Weyers et al., 2006; Enticott et al., 2014; but see Gold et al., 2013), dynamic emotional stimuli may facilitate or change emotion recognition while protagonists wear masks. It is also possible that actors wearing masks may change how they emote with their upper face features, as suggested by Okazaki et al. (2021). Future work is needed to understand the commonalities and differences in emotional communication in static and dynamic experimental conditions. Second, here we focused on understanding how facial occlusion and emotional context impacted understanding of happy and sad emotional expressions, but previous work has shown that face masks impair the perception of all six basic emotions (e.g., McCrackin et al., 2022a). An interesting next step would be to investigate whether availability of a congruent context can also reduce the impact of masks on recognition of other basic emotions as well. It is possible that understanding emotions with diagnostic upper face features (e.g., fear) may not be as impacted by contextual manipulations as understanding emotions with diagnostic lower face features (e.g., disgust) when lower visual features are occluded by masks. Opposite results may be expected for eye coverings. Third, we focused on the use of face masks as visual occluders, but there is evidence to suggest that the type of face occlusion may matter (Wang et al., 2015). For example, Fischer et al. (2012) reported that covering the lower face with a niqab led to a bias to perceive emotions as more negative, while Kret and Fischer (2018) reported key differences in how emotions were recognized when lower faces were covered by a western winter scarf relative to a niqab. Face masks themselves may now have implied positive or negative responses depending on the participant and their experiences, so future studies can examine the role of the type of face covering in social attribution effects. Finally, individual participant factors may have also played a role in our results. For example, our sample was mostly western, female skewed, and educated young adults. Individual factors such as gender (e.g., Hoffmann et al., 2010; Abbruzzese et al., 2019; Gamsakhurdashvili et al., 2021), age (Abbruzzese et al., 2019; Carbon, 2020), and cultural experience (Elfenbein et al., 2002) have been shown to play a role in emotion recognition. For example, women appear to be better at detecting subtle facial emotions (Hoffmann et al., 2010), and thus our participants may have better emotions recognition overall (from masked and unmasked faces). An important next step would be to examine if these results generalize to a more diverse sample.

In summary, wearing face masks lowers our ability to infer emotional states in others, with inferences about happy emotional states affected more than inferences about sad emotional states. This negative impact of visual occlusion by face masks can be reduced by incorporating verbal statements which provide congruent emotional context.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/9bmr3/?view_only=e0871f7add364e378eccd9920f60d98b.

Ethics statement

The studies involving human participants were reviewed and approved by the McGill University REB. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

SM and JR were involved in the early conceptualization and experimental design. SM oversaw the study programming and carried out data processing and analysis with advice from JR. SM wrote the initial manuscript draft, which was later revised and approved by both authors.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abbruzzese, L., Magnani, N., Robertson, I. H., and Mancuso, M. (2019). Age and gender differences in emotion recognition. *Front. Psychol.* 10:2371. doi: 10.3389/fpsyg.2019.02371

Addington, J., Saeedi, H., and Addington, D. (2006). Facial affect recognition: A mediator between cognitive and social functioning in psychosis?. *Schizoph. Res.* 85, 142–150. doi: 10.1016/j.schres.2006.03.028

Anderson, A. K., and Sobel, N. (2003). Dissociating intensity from valence as sensory inputs to emotion. *Neuron* 39, 581–583.

Baron-Cohen, S., and Cross, P. (1992). Reading the eyes: Evidence for the role of perception in the development of a theory of mind. *Mind Lang.* 7, 172–186. doi: 10.1111/j.1468-0017.1992.tb00203.x

Besel, L. D., and Yuille, J. C. (2010). Individual differences in empathy: The role of facial expression recognition. *Pers. Individ. Differ.* 49, 107–112. doi: 10.1016/j.paid.2010.03.013

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: An experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Blais, C., Roy, C., Fiset, D., Arguin, M., and Gosselin, F. (2012). The eyes are not the window to basic emotions. *Neuropsychologia* 50, 2830–2838. doi: 10.1016/j.neuropsychologia.2012.08.010

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C. C., and Serrano, M. (2021). The Impact of Face Masks on the Emotional Reading Abilities of Children—A Lesson From a Joint School–University Project. *IPerception* 12:20416695211038265. doi: 10.1177/20416695211038265

Cartaud, A., Quesque, F., and Coello, Y. (2020). Wearing a face mask against Covid-19 results in a reduction of social distancing. *PLoS One* 15:e0243023. doi: 10.1371/journal.pone.0243023

Clark, T. F., Winkielman, P., and McIntosh, D. N. (2008). Autism and the extraction of emotion from briefly presented facial expressions: Stumbling at the first step of empathy. *Emotion* 8:803. doi: 10.1037/a0014124

Colibazzi, T., Posner, J., Wang, Z., Gorman, D., Gerber, A., Yu, S., et al. (2010). Neural systems subserving valence and arousal during the experience of induced emotions. *Emotion* 10: 377.

Decety, J., Lewis, K. L., and Cowell, J. M. (2015). Specific electrophysiological components disentangle affective sharing and empathic concern in psychopathy. *J. Neurophysiol.* 114, 493–504. doi: 10.1152/jn.00253.2015

Ebner, N. C., Riediger, M., and Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behav. Res. Methods* 42, 351–362. doi: 10.3758/BRM.42.1.351

Eikenberry, S. E., Mancuso, M., Iboi, E., Phan, T., Eikenberry, K., Kuang, Y., et al. (2020). To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infect. Dis. Model.* 5, 293–308. doi: 10.1016/j.idm.2020.04.001

Ekman, P. (1999). Basic emotions. *Handb. Cogn. Emot.* 98:16.

Elfenbein, H. A., Mandal, M. K., Ambady, N., Harizuka, S., and Kumar, S. (2002). Cross-cultural patterns in emotion recognition: Highlighting design and analytical techniques. *Emotion* 2:75. doi: 10.1037/1528-3542.2.1.75

Enticott, P. G., Kennedy, H. A., Johnston, P. J., Rinehart, N. J., Tonge, B. J., Taffe, J. R., et al. (2014). Emotion recognition of static and dynamic faces in autism spectrum disorder. *Cogn. Emot.* 28, 1110–1118. doi: 10.1080/02699931.2013.867832

Fischer, A. H., Gillebaart, M., Rotteveel, M., Becker, D., and Vliek, M. (2012). Veiled emotions: The effect of covered faces on emotion perception and attitudes. *Soc. Psychol. Pers. Sci.* 3, 266–273. doi: 10.1177/1948550611418534

Gabrieli, G., and Esposito, G. (2021). Reduced Perceived Trustworthiness during Face Mask Wearing. *Eur. J. Investig. Health Psychol. Educ.* 11, 1474–1484. doi: 10.3390/ejihpe11040105

Gamsakhurdashvili, D., Antov, M. I., and Stockhorst, U. (2021). Facial Emotion Recognition and Emotional Memory From the Ovarian-Hormone Perspective: A Systematic Review. *Front. Psychol.* 12:641250. doi: 10.3389/fpsyg.2021.641250

Goeleven, E., De Raedt, R., Leyman, L., and Verschuere, B. (2008). The Karolinska directed emotional faces: A validation study. *Cogn. Emot.* 22, 1094–1118. doi: 10.1080/02699930701626582

Gold, J. M., Barker, J. D., Barr, S., Bittner, J. L., Bromfield, W. D., Chu, N., et al. (2013). The efficiency of dynamic and static facial expression recognition. *J. Vis.* 13, 23–23. doi: 10.1167/13.5.23

Grenville, E., and Dwyer, D. M. (2022). Face masks have emotion-dependent dissociable effects on accuracy and confidence in identifying facial expressions of emotion. *Cogn. Res.* 7:15. doi: 10.1186/s41235-022-00366-w

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hies, O., and Lewis, M. B. (2022). Beyond the beauty of occlusion: Medical masks increase facial attractiveness more than other face coverings. *Cogn. Res.* 7:1. doi: 10.1186/s41235-021-00351-9

Hoffmann, H., Kessler, H., Eppel, T., Rukavina, S., and Traue, H. C. (2010). Expression intensity, gender and facial emotion recognition: Women recognize only subtle facial emotions better than men. *Acta Psychol.* 135, 278–283. doi: 10.1016/j.actpsy.2010.07.012

Hugenberg, K., and Wilson, J. P. (2013). "Faces are central to social cognition," in *The Oxford handbook of social cognition*, ed. D. E. Carlston (Oxford: Oxford University Press), 167–193. doi: 10.1093/oxfordhb/9780199730018.013.0009

Kessinger, E. A., and Corkin, S. (2004). Two routes to emotional memory: Distinct neural processes for valence and arousal. *Proc. Natl. Acad. Sci. U.S.A.* 101, 3310–3315.

Kim, G., Seong, S. H., Hong, S. S., and Choi, E. (2022). Impact of face masks and sunglasses on emotion recognition in South Koreans. *PLoS One* 17:e0263466. doi: 10.1371/journal.pone.0263466

Klapper, A., Dotsch, R., van Rooij, I., and Wigboldus, D. H. (2016). Do we spontaneously form stable trustworthiness impressions from facial appearance? *J. Pers. Soc. Psychol.* 111:655.

Kret, M., and de Gelder, B. (2012). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Kret, M. E., and Fischer, A. H. (2018). Recognition of facial expressions is moderated by Islamic cues. *Cogn. Emot.* 32, 623–631. doi: 10.1080/02699931.2017.1330253

Leppänen, J. M., and Hietanen, J. K. (2001). Emotion recognition and social adjustment in school–aged girls and boys. *Scand. J. Psychol.* 42, 429–435. doi: 10.1111/1467-9450.00255

Leung, N. H., Chu, D. K., Shiu, E. Y., Chan, K. H., McDevitt, J. J., Hau, B. J., et al. (2020). Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat. Med.* 26, 676–680. doi: 10.1038/s41591-020-0843-2

Lundqvist, D., Flykt, A., and Öhman, A. (1998). Karolinska directed emotional faces. *Cogn. Emot.* 22, 1094–1118. doi: 10.1037/t27732-000

Marsh, A. A., Kozak, M. N., and Ambady, N. (2007). Accurate identification of fear facial expressions predicts prosocial behavior. *Emotion* 7:239. doi: 10.1037/1528-3542.7.2.239

McCrackin, S. D., Capozzi, F., Mayrand, F., and Ristic, J. (2022a). Face masks impair basic emotion recognition: Group effects and individual variability. *Soc. Psychol.* [Epub ahead of print]. doi: 10.1027/1864-9335/a000470

McCrackin, S. D., Provencher, S., Mendell, E., and Ristic, J. (2022b). Transparent masks reduce the negative impact of opaque masks on understanding emotional states but not on sharing them. *Cogn. Res.* 7:59. doi: 10.1186/s41235-022-00411-8

McCrackin, S. D., and Itier, R. J. (2021). Feeling through another's eyes: Perceived gaze direction impacts ERP and behavioural measures of positive and negative affective empathy. *NeuroImage* 226:117605. doi: 10.1016/j.neuroimage.2020.117605

Mheidly, N., Fares, M. Y., Zalzale, H., and Fares, J. (2020). Effect of face masks on interpersonal communication during the COVID-19 pandemic. *Front. Public Health* 8:582191. doi: 10.3389/fpubh.2020.582191

Mier, D., Lis, S., Neuthe, K., Sauer, C., Esslinger, C., Gallhofer, B., et al. (2010). The involvement of emotion recognition in affective theory of mind. *Psychophysiology* 47, 1028–1039. doi: 10.1111/j.1469-8986.2010.01031.x

Molnar-Szakacs, I., Uddin, L. Q., and Heffernan, M. B. (2021). The face behind the mask: The future of interpersonal interaction. *Neuron* 109, 1918–1920. doi: 10.1016/j.neuron.2021.05.030

Neath, K. (2012). *The use of facial features in facial expression discrimination*. Ph.D thesis, Waterloo: University of Waterloo.

Okazaki, S., Yamanami, H., Nakagawa, F., Takuwa, N., and Kawabata Duncan, K. J. (2021). Mask wearing increases eye involvement during smiling: A facial EMG study. *Sci. Rep.* 11:20370. doi: 10.1038/s41598-021-99872-y

Parada-Fernández, P., Herrero-Fernández, D., Jorge, R., and Comesaña, P. (2022). Wearing mask hinders emotion recognition, but enhances perception of attractiveness. *Pers. Individ. Differ.* 184:111195. doi: 10.1016/j.paid.2021.111195

Prather, K. A., Wang, C. C., and Schooley, R. T. (2020). Reducing transmission of SARS-CoV-2. *Science* 368, 1422–1424. doi: 10.1126/science.abc6197

Russell, J. A. (1980). A circumplex model of affect. *J. Pers. Soc. Psychol*. 39:1161.

Smith, M. L., Cottrell, G. W., Gosselin, F., and Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychol. Sci.* 16, 184–189. doi: 10.1111/j.0956-7976.2005.00801.x

Stewart, S. L., Schepman, A., Haigh, M., McHugh, R., and Stewart, A. J. (2019). Affective theory of mind inferences contextually influence the recognition of emotional facial expressions. *Cogn. Emot.* 33, 272–287. doi: 10.1080/02699931.2018.1450224

Svard, J., Wiens, S., and Fischer, H. (2012). Superior recognition performance for happy masked and unmasked faces in both younger and older adults. *Front. Psychol.* 3:520. doi: 10.3389/fpsyg.2012.00520

Švegar, D., Kardum, I., and Poliè, M. (2013). Happy face superiority effect in change detection paradigm. *Psihol. Teme* 22, 249–269.

Wang, Y., Thomas, J., Weissgerber, S. C., Kazemini, S., Ul-Haq, I., and Quadflieg, S. (2015). The headscarf effect revisited: Further evidence for a culture-based internal face processing advantage. *Perception* 44, 328–336. doi: 10.1068/p7940

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Weyers, P., Mühlberger, A., Hefele, C., and Pauli, P. (2006). Electromyographic responses to static and dynamic avatar emotional facial expressions. *Psychophysiology* 43, 450–453. doi: 10.1111/j.1469-8986.2006.00451.x

Wieser, M. J., and Brosch, T. (2012). Faces in context: A review and systematization of contextual influences on affective face processing. *Front. Psychol.* 3:471. doi: 10.3389/fpsyg.2012.00471

Williams, T. A., Porter, M. A., and Langdon, R. (2014). Social approach and emotion recognition in fragile X syndrome. *Am. J. Intellect. Dev. Disabil.* 119, 133–150. doi: 10.1352/1944-7558-119.2.133

Williams, W. C., Haque, E., Mai, B., and Venkatraman, V. (2021). Face masks influence how facial expressions are perceived: A drift-diffusion model of emotion judgments. *PsyArXiv* [Preprint]. doi: 10.31234/osf.io/a8yxf

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COVID-19 and psychiatric disorders: The impact of face masks in emotion recognition face masks and emotion recognition in psychiatry

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Since the outbreak of the COVID-19 pandemic, reading facial expressions has become more complex due to face masks covering the lower part of people's faces. A history of psychiatric illness has been associated with higher rates of complications, hospitalization, and mortality due to COVID-19. Psychiatric patients have well-documented difficulties reading emotions from facial expressions; accordingly, this study assesses how using face masks, such as those worn for preventing COVID-19 transmission, impacts the emotion recognition skills of patients with psychiatric disorders. To this end, the current study asked patients with bipolar disorder, major depressive disorder, schizophrenia, and healthy individuals to identify facial emotions on face images with and without facial masks. Results demonstrate that the emotion recognition skills of all participants were negatively influenced by face masks. Moreover, the main insight of the study is that the impairment is crucially significant when patients with major depressive disorder and schizophrenia had to identify happiness at a low-intensity level. These findings have important implications for satisfactory social relationships and well-being. If emotions with positive valence are hardly understood by specific psychiatric patients, there is an even greater requirement for doctor-patient interactions in public primary care.

KEYWORDS
COVID-19, emotion recognition, face masks, psychiatric disorders, happiness

Introduction

The impact and social consequences of the COVID-19 pandemic varied depending on factors such as social inequalities (1), age, gender (2), and the presence of medical (3) and psychiatric (4) conditions. Moreover, among individuals with mental health conditions, COVID-19 presents higher rates of complications, hospitalization, and

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mortality (5). The history of psychiatric illness confers a heightened vulnerability to disaster-related conditions (6).

Owing to the outbreak of the COVID-19 pandemic, the use of face masks has become somewhat widespread depending on different state laws and people's subjective attitudes (7). Although different beliefs about the effectiveness of this personal protective equipment, face mask has been widely adopted to reduce disease transmission (8, 9). Wearing face masks significantly impacts the human capacity to read facial expressions [for a comprehensive review, see (10)], making it more difficult to recognize people's emotions and their intensity (7, 11–14). The ancestral origin and crucial phylogenetic importance of the facial emotion recognition process in social interactions has been apparent since Darwin's first observations 150 years ago in his book "The Expression of the Emotions in Man and Animals" (15). His intuition has received further confirmations to date, due in particular to Paul Ekman's work (16). Reading facial expressions is an essential component of non-verbal communication in humans, together with head orientation (17), posture, body language (7) or characteristics of voice (18). While understanding affective expressions is a key social ability, its deficit is associated with severe difficulties in human interactions (19). Before the pandemic, studies reported that people had difficulty reading facial emotions when others were wearing some objects that cover parts of the face, for example: cardboard (20), a cap, or a scarf (21). More recently, studies on face masks reported that covering the lower part of the face altered the facial emotion reading (22), probably due to the constraint of focusing on the eye region compared to the mouth region (23, 24).

Mental illness conditions are often characterized by a different magnitude of impairments in social functioning and interpersonal interactions (25), linked to significant impairments in emotional expression reading. Participants with psychiatric disorders showed different degrees of impairment in facial emotion recognition (26). Such impacts on the emotional reading of faces mainly depend on shared alterations of dimensions such as mood (27), social cognition (28), or metacognition (29) among mental illnesses. Given the well-known disadvantages in social interactions of participants who present with a mental illness (Wild and Kornfeld 2021), the current study aims to assess how the widespread use of face masks impacts the emotion recognition skills in patients with psychiatric disorders.

For this purpose, we asked a group of participants with bipolar disorder (BD), major depressive disorder (MDD), schizophrenia (SZ), and a healthy control (HC) group to identify facial emotions on images with and without face masks. Our study tested varying intensities of facial expressions to investigate mild levels of impairment and recall more realistic facial configurations.

Methods

Sample

The current study recruited twenty-eight HC, 15 participants with BD, 20 participants with MDD, and 13 participants with SZ (see Table 1). The study excluded one participant with MDD and two participants with BD from the analyses because they were identified as outliers (i.e., a score in at least one task differing more than two standard deviations from the group's mean score). Thus, the remaining group was comprised of 28 HC (mean age ± standard deviation = 41.7 years old ± 11.8; females = 23), 13 participants with BD (39.6 years old ± 11.8; females = 5) 19 participants with MDD (48.4 years old ± 21.8; females = 15), and 13 participants with SZ (48.1 years old ± 8.5; females = 6). Groups were age-matched ($F_{(3,69)} = 1.5$, $p > 0.05$). The study included a power analysis based on previously published studies testing participants' ability to recognize emotion with and without masks among healthy adults (22), indicating a minimum of 13 participants was necessary to reach a power of 0.85 (two-tailed t-test, Cohen's d = 1.2, $\alpha = 0.05$).

All psychiatric patients were recruited from the Psychiatric Unit of San Martino Hospital in Genoa, and they were hospitalized while testing was occurring. The study recruited typical participants from the general population using advertising on social media and personal newsletters. Moreover, they underwent a clinical interview to exclude the presence of lifetime or current psychiatric disorders. Participants did not receive incentives of any kind for participating in the study. The Ethical Committee of IRCCS Ospedale Policlinico San Martino approved the study, and all participants gave their written informed consent.

Experimental paradigm

To investigate how face masks affect emotion recognition in psychiatric patients during hospitalization, we administered an internet-based questionnaire *via* smartphone. The questionnaire required participants to identify facial emotions on images with and without facial masks. Specifically, we replicated the paradigm that researchers previously used to test the effects of face masks on emotion recognition during childhood (22). This consisted of a standardized verbal-response test based on selecting an emotion's label (forced-choice) as a means to describe static pictures of human facial configurations. Such a choice favored the repeatability of the task and simplified the test administration to overcome the difficulties related to hospitalization and social distancing rules.

The task was structured in sequential blocks, showing first a block of pictures with facial masks, followed by a block of mask-free images. A total of 40 adult face pictures were

TABLE 1 Details of participants for the four groups involved in the study.

Group	Sample size *number*	Age *mean ± standard deviation*	Gender *number*
Healthy control (HC)	28	41.7 ± 11.8 years old	23 F, 5 M
Bipolar disorder (BD)	13	39.6 ± 11.8 years old	5 F, 8 M
Major depressive disorder (MDD)	19	48.4 ± 21.8 years old	15 F, 4 F
Schizophrenia (SZ)	13	48.1 ± 8.5 years old	6 F, 7 M

In gender, F, female and M, male.

FIGURE 1
Examples of low-intensity facial configuration with and without face masks for happiness, anger, sadness, and fear. Face images were obtained with permission from the ER-40 color emotional stimuli public database (30, 31).

presented in randomized order, including four repetitions of four facial emotions (happiness, sadness, fear, anger) with two levels of intensity (Low, High), in addition to a neutral facial expression that was presented 8 times to each participant. Figure 1 offers example images of happiness, sadness, fear and anger, with a low level of intensity. The original and modified pictures were obtained from the ER-40 color emotional stimuli database (30, 31), developed for the validated ER-40 test for facial emotion recognition (32, 33). A web designer modified pictures from the original database *ad hoc*, creating and adding realistic face masks for the set of images containing masks. We asked participants to identify their facial emotions by choosing five possible randomized options: happy, sad, fearful, angry, and neutral (see Figure 2).

To control for face mask exposure, the test occurred one year following the first lockdown's end in Italy (May 2021). Patients performed the test autonomously under the supervision of a clinical doctor, while typical participants performed it without supervision (the participants received specific written instructions, including the instruction to perform the task without any help). We did not impose time limits to provide answers.

Data analyses

For data analysis, we calculated performance as a percentage of correct responses with and without the masks. Performance was not normally distributed for one group (Shapiro-Wilk normality tests: HC: $W = 0.91$, $p < 0.01$; BD: $W = 0.95$, $p > 0.05$; MDD: $W = 0.96$, $p > 0.05$; SZ: $W = 0.97$, $p > 0.05$); we then ran ANOVAs based on permutation tests and permutation t-tests. We used the *aovp* function (*lmPerm* package) and the *perm.t.test* function (*MKinfer* package) in R to compute the analysis. First, for each emotion separately (i.e., Happiness, Sadness, Fear, Anger), we ran an ANOVA based on permutation tests with mask presence (i.e., Mask, NoMask) and intensity level of emotions (i.e., Low, High)

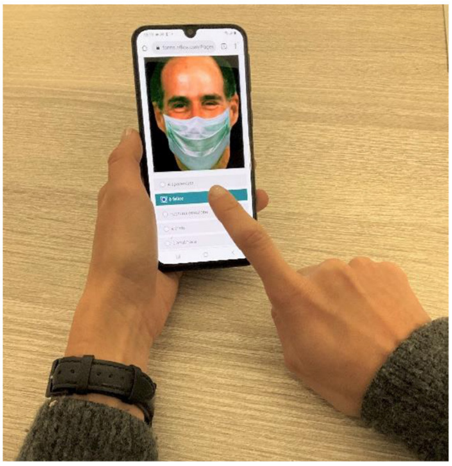

FIGURE 2
Experimental procedure. We asked participants to identify the correct facial emotion by choosing between five possible randomized options: happy, sad, fearful, angry, and neutral. Each face was displayed on the screen of personal smartphones for as long as it took to respond by holding an index finger against the touch screen. The study obtained face images with permission from the ER-40 color emotional stimuli public database (30, 31).

as within-subject factors and group (i.e., HC, BD, MDD, SZ) as between-subject factors. Considering there were no significant interactions between mask presence x intensity x group for anger, fear, and sadness but only for happiness, we focused subsequent analyses on emotional valence. We marked happiness as positive emotional valence, while grouping sadness, fear and anger into negative emotional valence. We thereby ran an ANOVA based on permutation tests with group (i.e., HC, BD, MDD, SZ) as between-subject factor, condition (i.e., Mask, NoMask), the intensity level of emotions (i.e., Low, High) and valence (i.e., Positive, Negative) as within-subject factors. We carried out follow-up ANOVAs using permutation tests and *post hoc* comparisons, applying Bonferroni correction to the results.

The intensity was absent as a variable for neutral faces. For the neutral expression, we performed a separate ANOVA based on permutation tests that considered only mask presence (i.e., Mask, NoMask) and group (i.e., HC, BD, MDD, SZ). Moreover, we computed confusion matrices to investigate the response distribution among different emotions with masks for each group.

Results

Results showed that face masks always negatively impact the human ability to recognize emotions from facial configurations, but in the current study, this was particularly true for patients with MDD and SZ who were asked to recognize low-intensity images with positive valence. Indeed, the ability of patients with MDD and SZ to infer happiness when happy facial configurations were relatively subtle is drastically influenced by face masks.

When considering each emotion separately, the interaction between mask presence x intensity x group appeared significant only for happiness, which offered the opportunity to group fear, anger and sadness and analyse them together based on their negative valence. Specifically, the interaction was insignificant for anger [$F_{(3,207)} = 0.1, p > 0.05$, Iter = 51], sadness [$F_{(3,207)} = 0.7, p > 0.05$, Iter = 556], and fear [$F_{(3,207)} = 0.2, p > 0.05$, Iter = 424]. Subsequently, the ANOVA considering mask presence, group, valence and level of intensity demonstrated a significant main effect of mask presence [$F_{(1,1,067)} = 54.7$, $p < 0.01$, Iter = 5,000], group [$F_{(3,69)} = 6.5$, $p < 0.01$, Iter = 5,000], valence [$F_{(1,1,067)} = 184.7$, $p < 0.01$, Iter = 5,000] and level intensity [$F_{(1,1,067)} = 54.7$, $p < 0.01$, Iter = 5,000]. Moreover, this analysis revealed a significant interaction between the involved factors [mask presence x group x valence x level of intensity: $F_{(3,1067)} = 2$, $p < 0.01$, Iter = 5,000].

Concerning the emotion with positive valence (i.e., happiness, Figure 3 top), the follow-up analyses demonstrated a significant interaction between mask presence x group x level of intensity [$F_{(3,276)} = 4.8$, $p < 0.05$, Iter = 5,000], allowing us to separately analyse the two levels of intensity. For high-intensity emotions with positive valence (Figure 3A) only a significant main effect of mask presence emerged [$F_{(1,69)} = 3.8$, $p < 0.01$, Iter = 2,865], while there was no significant effects for group [$F_{(3,69)} = 2.1$, $p > 0.05$, Iter = 724] and the interaction mask presence x group [$F_{(3,69)} = 1.6$, $p > 0.05$, Iter = 1,377]. Instead, for low-intensity emotions with positive valence (Figure 3B), the interaction between mask presence and group was statistically significant [$F_{(3,69)} = 6.6$, $p < 0.01$, Iter = 5,000]. *Post hoc* permutation *t*-tests showed masks' presence reduced a participant's ability to recognize emotions with positive valence for HC [$t_{(37.8)} = -2.2$, $p < 0.01$, Iter = 5,000], MDD patients [$t_{(18)} = -5.9$, $p < 0.01$, Iter = 5,000], and SZ patients [$t_{(16.4)} = -3.5$, $p < 0.01$, Iter = 5,000], but not BD patients [$t_{(24)} = 0.0001$, $p > 0.05$, Iter = 5,000]. Moreover, while patients and control participants performed similarly without masks [for HC vs. BD: $t_{(20.2)} = 0.3$, $p > 0.05$, Iter = 5,000; for HC vs. MDD: $t_{(27)} = -1.8$, $p > 0.05$, Iter = 5,000; for HC vs. SZ: $t_{(20.2)} = 0.4$, $p > 0.05$, Iter = 5,000; for BD vs. MDD: $t_{(12)} = 1.5$, $p > 0.05$, Iter = 400; for BD vs. SZ: $t_{(24)} = 0.0001$, $p > 0.05$, Iter = 5,000; for MDD vs. SZ: $t_{(12)} = 1.5$, $p > 0.05$, Iter = 400], analyses showed some differences between groups when masks covered half of one's face. Specifically, MDD patients performed worse than HC participants [$t_{(35.5)} = 2.8$, $p < 0.01$, Iter = 5,000], and BD patients [$t_{(27.5)} = -4.3$, $p < 0.01$, Iter = 5,000]. Similarly, SZ patients performed worse than HC [$t_{(19.4)} = 2.4$, $p < 0.01$, Iter = 5,000] and BD patients [$t_{(16.4)} = 3.5$, $p < 0.01$, Iter = 5,000]. HC participants and BD patients had similar performance with masks [$t_{(37.8)} = -1.6$, $p > 0.05$, Iter

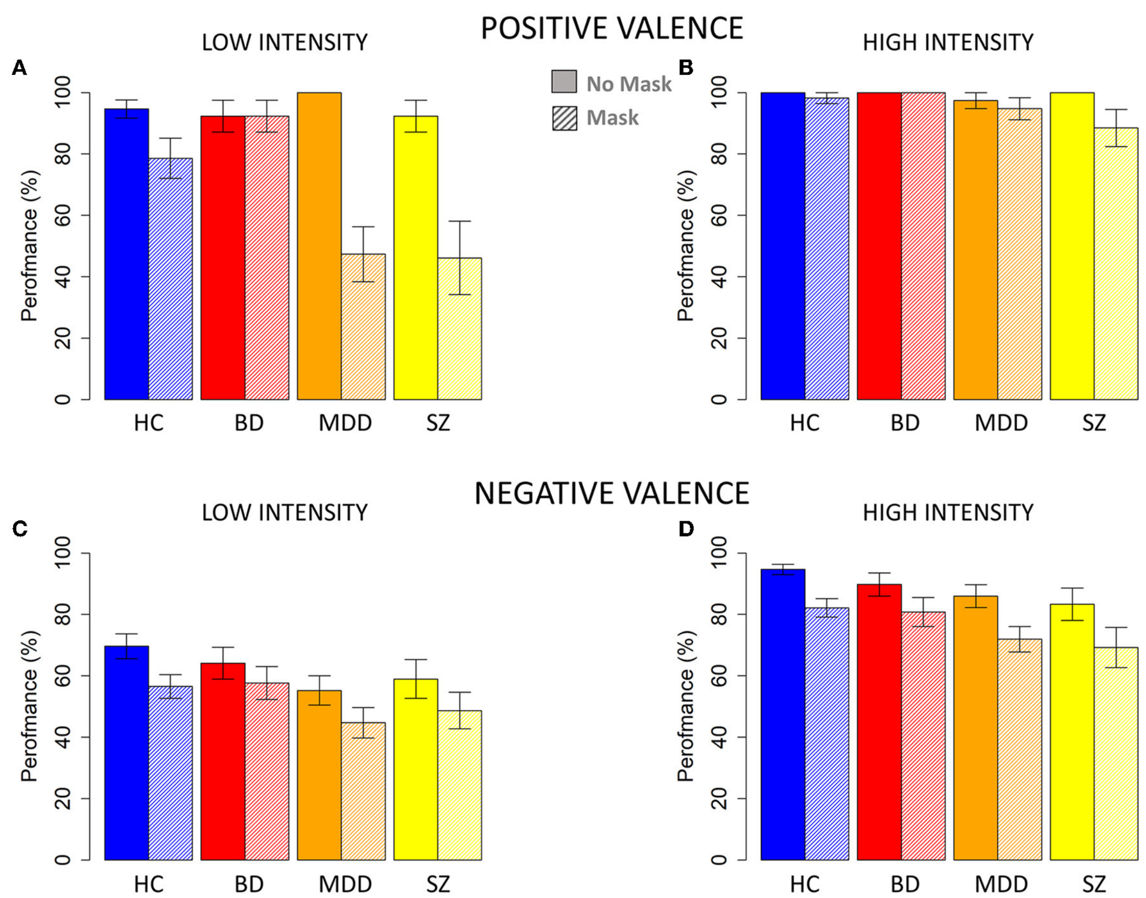

FIGURE 3
Percentage of correct responses without and with face masks for each group. **(A)** Performance for images with low-level positive valence. **(B)** Performance for images with high-level positive valence. **(C)** Performance for images with low-level negative valence. **(D)** Performance for images with high-level negative valence. HC, healthy control; BD, patients with bipolar disorder; MDD, patients with major depressive disorder; SZ, patients with schizophrenia. Filled and shaded color bars represent images without and with face masks, respectively. The standard error of the mean (SEM) is reported.

= 5,000], as did MDD and SZ patients [$t_{(24.1)} = 0.08$, $p > 0.05$, Iter = 5,000].

For emotions with negative valence (Figure 3 bottom), the interaction mask presence x group x level of intensity was insignificant [$F_{(3,791)} = 0.07$, $p > 0.05$, Iter = 51]. The analysis showed an overall decrease of performance correlated with mask presence [$F_{(1,791)} = 54.7$, $p < 0.01$, Iter = 5,000], low level of intensity [$F_{(1,791)} = 184.7$, $p < 0.01$, Iter = 5,000] and group [$F_{(3,69)} = 6.5$, $p < 0.01$, Iter = 5,000]. As Figures 3C,D indicate, the percentage of corrected responses gradually decreased independent of intensity level among HC participants, patients with BD, patients with MDD, and patients with SZ.

When analyzing neutral expressions, we observed that masks similarly affected the performance of all participants, with no differences between groups. Indeed, a main effect of mask presence emerged from the ANOVA on performance [$F_{(1,69)} = 8.5$, $p < 0.01$, Iter = 4,913] but not a main effect of group [$F_{(3,69)} = 1.9$, $p > 0.05$, Iter = 432] or an interaction between mask presence and group [$F_{(1,69)} = 1.9$, $p > 0.05$, Iter = 962].

Figure 4 presents response distribution among different emotions with masks, indicating the matrices of confusion for low and high levels of intensity emotions for HC, BD, MDD, and SZ individuals, respectively. We excluded the responses to neutral expressions as they do not involve two levels of intensity. All participants confused the correct emotion with other emotions more often when the mask was present. For all groups, confusion increased in the low-intensity condition, and this was especially true for MDD and SZ patients. The most challenging emotion to recognize was anger in line with (30, 33), which participants typically recognized as a neutral expression or sadness. Participants regularly misrecognized happy faces covered with masks as neutral expressions, while also confusing

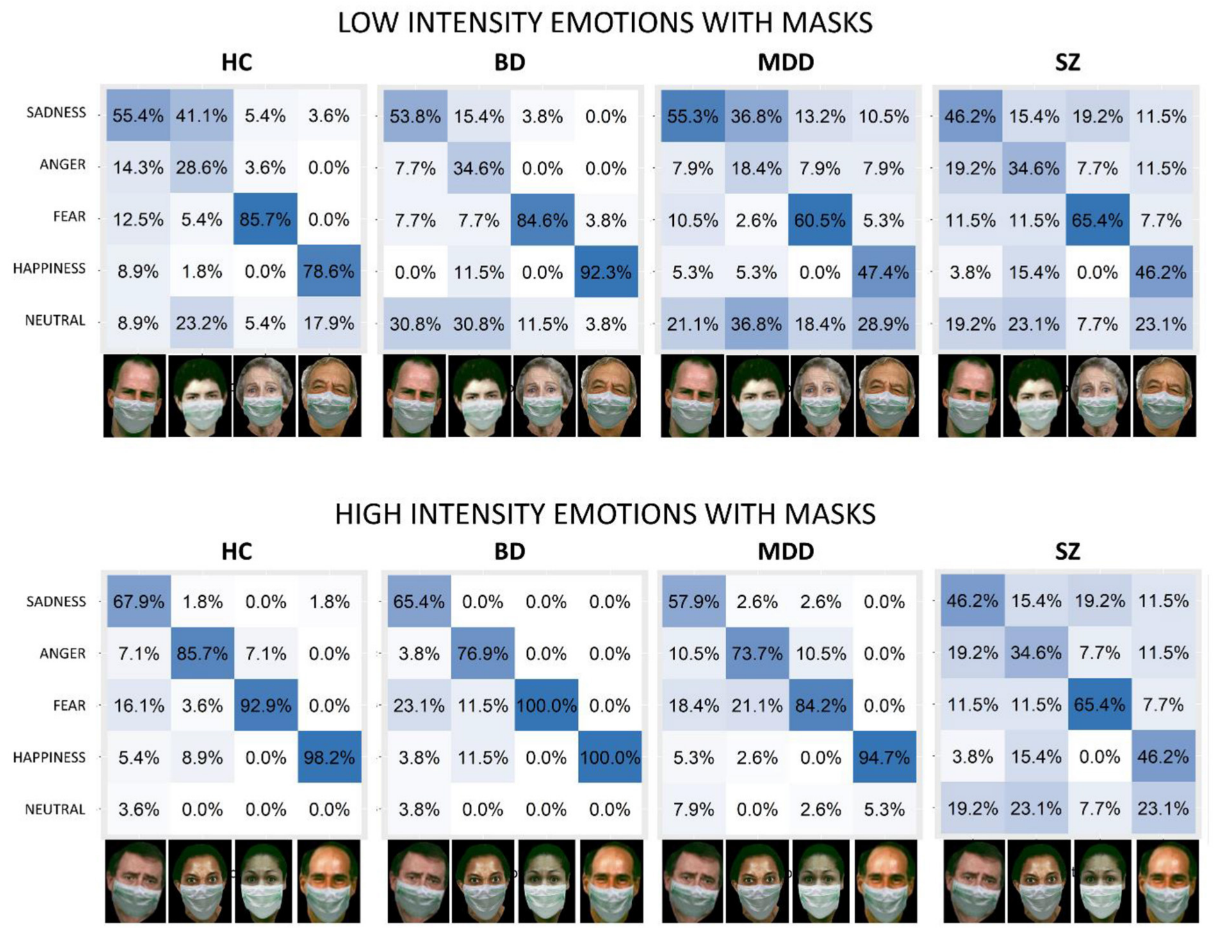

FIGURE 4
Confusion matrices for emotion inference from low-intensity **(bottom)** and high-intensity **(top)** facial configurations with face masks for all groups. The x-axis shows the presented stimuli. The y-axis shows the emotions perceived by participants. Columns report the percentage of responses for each emotion. HC, healthy control; BD, patients with bipolar disorder; MDD, patients with major depressive disorder; SZ, patients with schizophrenia. Face images were obtained with permission from the ER-40 color emotional stimuli public database (30, 31).

sad faces covered with masks with neutral expressions and all the other emotions.

Discussion

In this study, we investigated whether psychiatric patients, and particularly those affected by BD, SZ, and MDD, have more difficulties than healthy people recognizing facial emotions with a part of the face covered by a face mask. We demonstrated that using face masks overall reduces recognition performance across all individuals. Moreover, hiding the lower part of the face with face masks specifically impairs the recognition of subtle happy faces for SZ and MDD.

We replicated literature findings of a negative effect in recognizing facial expressions due to face masks (14, 22, 34). As expected, in specific cases, the difficulty is much higher for psychiatric patients. Indeed, impairment is particularly intense for positive faces with low-intensity emotional valence: face masks critically altered the chances of MDD and SZ participants recognizing happiness when it is slight. These results further confirm the importance of the mouth region in recognizing this emotion (23, 35). The reason for the drop in performance in MDD and SZ individuals when they must recognize low-intensity happy faces with masks may result from the negative symptoms these groups of patients share. An inverse association has been shown between the accuracy in recognizing happy expressions and depression severity (36). As well, depression drives people to bias facial expressions toward negative emotions like sadness, thus under-recognizing happy facial expressions in comparison with healthy participants (36). Given the crucial importance of the mouth to infer the facial expression of happiness (37), it is reasonable to hypothesize that when a mask covers this region there results in a real struggle to recognize happiness in the presence of negative symptoms. A ceiling effect for low-intensity happiness without masks might also underly the lack of differences between the two groups of patients and, if this is the case, this limits the generalizability of our results to real-life situations. Indeed, for high-intensity positive emotions with and without masks, and low-intensity positive without masks, we did not observe significant differences between the groups (SZ, MDD, BD, and HC). The lack of differences between patients and controls in these conditions is likely due to the dataset of images that involves very clear stimuli concerning positive emotions, evoking ceiling effects (33). In contrast to the commonly used emotion recognition tasks, we chose to use an easier task to emphasize the difference between the masked vs. non-masked conditions. Another non-mutually exclusive hypothesis is that the presence of masks during the year of COVID-19 before our experiment helped patients in their overall ability to recognize emotions. We can speculate that focusing only on the eyes during the pandemic improved skills to recognize facial expressions; when only half the face is available, patients generally had to learn to be more responsive to eye cues. If this is the case, patients still face difficulties when masks cover part of the face but became more similar to HC when the whole face was visible. Further research is necessary to validate this latter hypothesis. The fact that the performance drastically decreases when low-intensity happy expressions are covered with masks stresses the importance of the mouth region in recognizing happiness when negative symptoms are present.

As for emotion with negative valence (i.e., fear, anger, and sadness), we observed that the presence of masks similarly impacted the performance of all participants. We hypothesize that the deficit associated with the mask is present in all groups but not particularly impairing. This is because recognizing anger and fearful expressions largely requires information from the eyes (38–40). In line with previous results, performance significantly decreases with reduced intensity (33) and, independent of intensity level, the percentage of corrected responses was higher for HC and decreased for BD, followed by MDD and SZ. This agrees with the overall difficulty of psychiatric patients in reading facial emotions. For instance, a recent review by Krause et al. (36) stresses the existence of a broad facial emotion recognition deficit in individuals suffering from MDD. Among participants affected with BD, available evidence accounted for a global or selective facial expression recognition deficit in euthymic participants, or during the active phase of illness in nearly 2/3 of the available studies (41). Patients affected with BD are significantly less accurate when it comes to recognizing facial emotions but particularly fear (42, 43). Since the first episode, psychotic patients displayed a global impairment in recognizing facial affective expressions, and in particular negative emotions like fear and anger (28). Similarly, participants with SZ are generally insensitive or misrecognized negative emotions such as sadness, fear, and anger (44) while also being more likely to misinterpret happy faces (45). In SZ patients, the abnormal face processing seems to depend on a faulty structural encoding of faces (45, 46) and on the tendency to visually scan features of the face that are not important in the expression of a specific emotion (47).

Regarding neutral expressions, our study agrees with previous findings that reported a certain difficulty in recognizing the neutral expression, a difficulty accentuated when the face mask is worn (39, 48).

To conclude, the outcome of our work is that wearing a face mask makes each facial expression much more complex to recognize, regardless of the underlying psychological disorder. However, when the face mask is on, difficulties in recognizing happy facial emotions become even more severe for SZ and MDD patients. Nevertheless, this study has some limitations for which to account when interpreting the results: samples were relatively small and unequal in terms of the number of participants; the visual input includes different positions of the head, head tilt, etc. beyond information about facial emotions; all patients were hospitalized at the moment of testing, questioning the generalizability of results when it comes to applying them to non-hospitalized people suffering from mental health conditions; the experimental setup challenges the ecological validity of a computerized test vs. real-life situations. Furthermore, future studies should address possible effects resulting from a lack of gender-matched samples. Indeed, emotion recognition is gender specific, with females known to better perform (49–51), and females predominated our sample of MDD in line with the skewed gender ratio for this psychiatric condition (51). Females also predominated the HC group because we purposefully matched it with the gender bias of the MDD group. Moreover, we cannot completely rule out other potential confounds, such as visual acuity, previous experience with this kind of paradigm, or personality traits. Although further research is necessary, our findings retain important clinical implications. They may explain why the use of portrait photos with smiling faces positively affects patients' perceptions of healthcare staff (52). Additionally, the impairment of positive implicit communication might contribute to misinterpretation of other intentions and emotions during social relationships (53), with negative consequences on clinical interactions with patients of mental health workers such as psychiatrists, psychologists, psychiatric rehabilitation technicians, or nurses. Moreover, recognizing emotions with positive valence is crucial for the patient's social interactions and well-being in general.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethical Committee of IRCCS Ospedale Policlinico San Martino. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AE, MBA, DE, and BP collected the data and organized the database. MBA performed the statistical analysis. AE, MBA, and AR wrote the first draft of the manuscript. AT helped to revised the manuscript. All authors contributed to the conception and design of the study, revising, reading, and approving the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Magesh S, John D, Li WT, Li Y, Mattingly-App A, Jain S, et al. Disparities in COVID-19 outcomes by race, ethnicity, and socioeconomic status: a systematic-review and meta-analysis. *JAMA Netw open.* (2021) 4:e2134147. doi: 10.1001/jamanetworkopen.2021.34147

2. Barek MA, Aziz MA, Islam MS. Impact of age, sex, comorbidities and clinical symptoms on the severity of COVID-19 cases: a meta-analysis with 55 studies and 10,014 cases. *Heliyon.* (2020) 6:e05684. doi: 10.1016/j.heliyon.2020.e05684

3. Thakur B, Dubey P, Benitez J, Torres JP, Reddy S, Shokar N, et al. A systematic review and meta-analysis of geographic differences in comorbidities and associated severity and mortality among individuals with COVID-19. *Sci Rep.* (2021) 11:8562. doi: 10.1038/s41598-021-88130-w

4. Campion J, Javed A, Lund C, Sartorius N, Saxena S, Marmot M, et al. Public mental health: required actions to address implementation failure in the context of COVID-19. *Lancet Psychiatry.* (2022) 9:169. doi: 10.1016/S2215-0366(21)00199-1

5. Hassan L, Peek N, Lovell K, Carvalho AF, Solmi M, Stubbs B, et al. Disparities in COVID-19 infection, hospitalisation and death in people with schizophrenia, bipolar disorder, and major depressive disorder: a cohort study of the UK biobank. *Mol Psychiatry.* (2021) 27:1248–55. doi: 10.1038/s41380-021-01344-2

6. Brooks SK, Webster RK, Smith LE, Woodland L, Wessely S, Greenberg N, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet.* (2020) 395:912–20. doi: 10.1016/S0140-6736(20)30460-8

7. Carbon CC. Wearing face masks strongly confuses counterparts in reading emotions. *Front Psychol.* (2020) 11:566886. doi: 10.3389/fpsyg.2020.566886

8. Baxter-King R, Brown JR, Enos RD, Naeim A, Vavreck L. How local partisan context conditions prosocial behaviors: Mask wearing during COVID-19. *Proc Natl Acad Sci U S A.* (2022) 119:e2116311119. doi: 10.1073/pnas.2116311119

9. Collis A, Garimella K, Moehring A, Rahimian MA, Babalola S, Gobat NH, et al. Global survey on COVID-19 beliefs, behaviours and norms. *Nat Hum Behav.* (2022) 1–8. doi: 10.1038/s41562-022-01347-1. [Epub ahead of print].

10. Pavlova MA, Sokolov AA. Reading covered faces. *Cereb Cortex.* (2022) 32:249–65. doi: 10.1093/cercor/bhab311

11. Henke L, Guseva M, Wagemans K, Pischedda D, Haynes J-D, Jahn G, et al. Surgical face masks do not impair the decoding of facial expressions of negative affect more severely in older than in younger adults. *Cogn Res Princ Implic.* (2022) 7:63. doi: 10.1186/s41235-022-00403-8

12. Pavlova MA, Sokolov AA. Reading language of the eyes. *Neurosci Biobehav Rev.* (2022) 140:104755–104755. doi: 10.1016/j.neubiorev.2022.104755

13. Proverbio AM, Cerri A. The recognition of facial expressions under surgical masks: the primacy of anger. *Front Neurosci.* (2022) 16:864490. doi: 10.3389/fnins.2022.864490

14. Tsantani M, Podgajecka V, Gray KLH, Cook R. How does the presence of a surgical face mask impair the perceived intensity of facial emotions? *PLoS ONE.* (2022) 17:e0262344. doi: 10.1371/journal.pone.0262344

15. Waller BM, Julle-Daniere E, Micheletta J. Measuring the evolution of facial "expression" using multi-species FACS. *Neurosci Biobehav Rev.* (2020) 113:1–11. doi: 10.1016/j.neubiorev.2020.02.031

16. Wolf K. Measuring facial expression of emotion. *Dialogues Clin Neurosci.* (2015) 17:457–62. doi: 10.31887/DCNS.2015.17.4/kwolf

17. Sauer A, Mothes-Lasch M, Miltner WHR, Straube T. Effects of gaze direction, head orientation and valence of facial expression on amygdala activity. *Soc Cogn Affect Neurosci.* (2014) 9:1246–52. doi: 10.1093/scan/nst100

18. Aviezer H, Hassin RR, Ryan J, Grady C, Susskind J, Anderson A, et al. Angry, disgusted, or afraid? Studies on the malleability of emotion perception. *Psychol Sci.* (2008) 19:724–32. doi: 10.1111/j.1467-9280.2008.02148.x

19. Avery SN, VanDerKlok RM, Heckers S, Blackford JU. Impaired face recognition is associated with social inhibition. *Psychiatry Res.* (2016) 236:53. doi: 10.1016/j.psychres.2015.12.035

20. Bassili JN. Emotion recognition: the role of facial movement and the relative importance of upper and lower areas of the face. *J Pers Soc Psychol.* (1979) 37:2049–58. doi: 10.1037/0022-3514.37.11.2049

21. Kret ME, Gelder de B. Islamic headdress influences how emotion is recognized from the eyes. *Front Psychol.* (2012) 3:110. doi: 10.3389/fpsyg.2012.00110

22. Gori M, Schiatti L, Amadeo MB. Masking emotions: face masks impair how we read emotions. *Front Psychol.* (2021) 12:1541. doi: 10.3389/fpsyg.2021.669432

23. Blais C, Roy C, Fiset D, Arguin M, Gosselin F. The eyes are not the window to basic emotions. *Neuropsychologia.* (2012) 50:2830–8. doi: 10.1016/j.neuropsychologia.2012.08.010

24. Jack RE, Blais C, Scheepers C, Schyns PG, Caldara R. Cultural confusions show that facial expressions are not universal. *Curr Biol.* (2009) 19:1543–8. doi: 10.1016/j.cub.2009.07.051

25. Høegh MC, Melle I, Aminoff SR, Olsen SH, Lunding SH, Ueland T, et al. Affective lability and social functioning in severe mental disorders. *Eur Arch Psychiatry Clin Neurosci*. (2022) 272:873–85. doi: 10.1007/s00406-022-01380-1

26. Coleman JRI, Lester KJ, Keers R, Munafò MR, Breen G, Eley TC, et al. Genome-wide association study of facial emotion recognition in children and association with polygenic risk for mental health disorders. *Am J Med Genet B Neuropsychiatr Genet*. (2017) 174:701–11. doi: 10.1002/ajmg.b.32558

27. Surguladze SA, Senior C, Young AW, Brébion G, Travis MJ, Phillips ML, et al. Recognition accuracy and response bias to happy and sad facial expressions in patients with major depression. *Neuropsychology.* (2004) 18:212–8. doi: 10.1037/0894-4105.18.2.212

28. Tripoli G, Quattrone D, Ferraro L, Gayer-Anderson C, La Cascia C, La Barbera D, et al. Facial emotion recognition in psychosis and associations with polygenic risk for schizophrenia: findings from the multi-center EU-GEI case-control study. *Schizophr Bull.* (2022) 48:1104–14. doi: 10.1093/schbul/sbac022

29. Lysaker PH, Chernov N, Moiseeva T, Sozinova M, Dmitryeva N, Alyoshin V, et al. The association of metacognition with emotion recognition and perspective taking in a Russian sample with psychosis. *J Clin Psychol.* (2021) 77:1034–44. doi: 10.1002/jclp.23076

30. Gur RC, Sara R, Hagendoorn M, Marom O, Hughett P, Macy L, et al. A method for obtaining 3-dimensional facial expressions and its standardization for use in neurocognitive studies. *J Neurosci Methods.* (2002) 115:137–43. doi: 10.1016/S0165-0270(02)00006-7

31. Pinkham AE, Sasson NJ, Calkins ME, Richard J, Hughett P, Gur RE, et al. The other-race effect in face processing among African American and Caucasian individuals with schizophrenia. *Am J Psychiatry.* (2008) 165:639–45. doi: 10.1176/appi.ajp.2007.07101604

32. Carter CS, Barch DM, Ruben G, Raquel G, Pinkham A, Ochsner K. CNTRICS final task selection: social cognitive and affective neuroscience-based measures. *Schizophr Bull*. (2009) 35:153–62. doi: 10.1093/schbul/sbn157

33. Kohler CG, Turner TH, Gur RE, Gur RC. Recognition of facial emotions in neuropsychiatric disorders. *CNS Spectr.* (2004) 9:267–74. doi: 10.1017/S1092852900009202

34. Grundmann F, Epstude K, Scheibe S. Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS ONE.* (2021) 16:e0249792. doi: 10.1371/journal.pone.0249792

35. Roberson D, Kikutani M, Döge P, Whitaker L, Majid A. Shades of emotion: what the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition.* (2012) 125:195–206. doi: 10.1016/j.cognition.2012.06.018

36. Krause FC, Linardatos E, Fresco DM, Moore MT. Facial emotion recognition in major depressive disorder: a meta-analytic review. *J Affect Disord.* (2021) 293:320–8. doi: 10.1016/j.jad.2021.06.053

37. Eisenbarth H, Alpers GW. Happy mouth and sad eyes: scanning emotional facial expressions. *Emotion.* (2011) 11:860–5. doi: 10.1037/a0022758

38. Noyes E, Davis JP, Petrov N, Gray KLH, Ritchie KL. The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R Soc open Sci.* (2021) 8:201169. doi: 10.1098/rsos.201169

39. Smith ML, Cottrell GW, Gosselin F, Schyns PG. Transmitting and decoding facial expressions. *Psychol Sci.* (2005) 16:184–9. doi: 10.1111/j.0956-7976.2005.00801.x

40. Wegrzyn M, Vogt M, Kireclioglu B, Schneider J, Kissler J. Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS ONE.* (2017) 12:e0177239. doi: 10.1371/journal.pone.0177239

41. Miskowiak KW, Seeberg I, Kjaerstad HL, Burdick KE, Martinez-Aran A, del Mar Bonnin C, et al. Affective cognition in bipolar disorder: s systematic review by the ISBD targeting cognition task force. *Bipolar Disord*. (2019) 21:686–719. doi: 10.1111/bdi.12834

42. Furlong LS, Rossell SL, Karantonis JA, Cropley VL, Hughes M, Van Rheenen TE, et al. Characterization of facial emotion recognition in bipolar disorder: focus on emotion mislabelling and neutral expressions. *J Neuropsychol*. (2021) 16:353–72. doi: 10.1111/jnp.12267

43. Rocca CCDA, Van Den Heuvel E, Caetano SC, Lafer B. Facial emotion recognition in bipolar disorder: a critical review. *Rev Bras Psiquiatr.* (2009) 31:171–80. doi: 10.1590/S1516-44462009000200015

44. Lee SC, Lin GH, Shih CL, Chen KW, Liu CC, Kuo CJ, et al. Error patterns of facial emotion recognition in patients with schizophrenia. *J Affect Disord.* (2022) 300:441–8. doi: 10.1016/j.jad.2021.12.130

45. Turetsky BI, Kohler CG, Indersmitten T, Bhati MT, Charbonnier D, Gur RC, et al. Facial emotion recognition in schizophrenia: when and why does it go awry? *Schizophr Res.* (2007) 94:253–63. doi: 10.1016/j.schres.2007.05.001

46. Wynn JK, Lee J, Horan WP, Green MF. Using event related potentials to explore stages of facial affect recognition deficits in schizophrenia. *Schizophr Bull.* (2008) 34:679–87. doi: 10.1093/schbul/sbn047

47. Kohler CG, Walker JB, Martin EA, Healey KM, Moberg PJ. Facial emotion perception in schizophrenia: a meta-analytic review. *Schizophr Bull.* (2010) 36:1009–19. doi: 10.1093/schbul/sbn192

48. Duncan J, Gosselin F, Cobarro C, Dugas G, Blais C, Fiset D, et al. Orientations for the successful categorization of facial expressions and their link with facial features. *J Vis.* (2017) 17:7. doi: 10.1167/17.14.7

49. Herlitz A, Lovén J. Sex differences and the own-gender bias in face recognition: a meta-analytic review. *Vis Cogn.* (2014) 21:1306–36. doi: 10.1080/13506285.2013.823140

50. Mishra MV, Likitlersuang J, Wilmer B, Cohan J, Germine S, DeGutis L, et al. Gender differences in familiar face recognition and the influence of sociocultural gender inequality. *Sci Rep*. (2019) 9:17884. doi: 10.1038/s41598-019-54074-5

51. Salk RH, Hyde JS, Abramson LY. Gender differences in depression in representative national samples: meta-analyses of diagnoses and symptoms. *Psychol Bull.* (2017) 143:783–822. doi: 10.1037/bul0000102

52. Wiesmann M, Franz C, Sichtermann T, Minkenberg J, Mathern N, Stockero A, et al. Seeing faces, when faces can't be seen: wearing portrait photos has a positive effect on how patients perceive medical staff when face masks have to be worn. *PLoS ONE.* (2021) 16:e0251445. doi: 10.1371/journal.pone.0251445

53. Wong CKM, Yip BHK, Mercer S, Griffiths S, Kung K, Wong MCS, et al. Effect of facemasks on empathy and relational continuity: a randomised controlled trial in primary care. *BMC Fam Pract.* (2013) 14:200. doi: 10.1186/1471-2296-14-200

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Ties between reading faces, bodies, eyes, and autistic traits

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While reading covered with masks faces during the COVID-19 pandemic, for efficient social interaction, we need to combine information from different sources such as the eyes (without faces hidden by masks) and bodies. This may be challenging for individuals with neuropsychiatric conditions, in particular, autism spectrum disorders. Here we examined whether reading of dynamic faces, bodies, and eyes are tied in a gender-specific way, and how these capabilities are related to autistic traits expression. Females and males accomplished a task with point-light faces along with a task with point-light body locomotion portraying different emotional expressions. They had to infer emotional content of displays. In addition, participants were administered the Reading the Mind in the Eyes Test, modified and Autism Spectrum Quotient questionnaire. The findings show that only in females, inferring emotions from dynamic bodies and faces are firmly linked, whereas in males, reading in the eyes is knotted with face reading. Strikingly, in neurotypical males only, accuracy of face, body, and eyes reading was negatively tied with autistic traits. The outcome points to gender-specific modes in social cognition: females rely upon merely dynamic cues while reading faces and bodies, whereas males most likely trust configural information. The findings are of value for examination of face and body language reading in neuropsychiatric conditions, in particular, autism, most of which are gender/sex-specific. This work suggests that if male individuals with autistic traits experience difficulties in reading covered with masks faces, these deficits may be unlikely compensated by reading (even dynamic) bodies and faces. By contrast, in females, reading covered faces as well as reading language of dynamic bodies and faces are not compulsorily connected to autistic traits preventing them from paying high costs for maladaptive social interaction.

KEYWORDS

reading covered faces, point-light body motion, body language reading, face reading, gender, reading in the eyes, social cognition, autistic traits

Introduction

Mandatory covering faces with medical masks may lead to difficulties in social perception and interaction (for comprehensive review, see Pavlova and Sokolov, 2022a). For achieving efficient social interaction during the COVID-19 pandemic, we are forced, therefore, to combine social signals from different sources such as the eyes (with a face hidden behind a mask) and bodies. This is particularly challenging for individuals with neuropsychiatric conditions such as autism spectrum disorders (ASD) characterized by aberrant social cognition already in the pre-pandemic period.

Face and body language reading is vital for efficient interpersonal exchanges. Examination of social competence by using dynamic input is of importance, since in daily-life social interaction and non-verbal communication we never deal with motionless static faces and bodies. Over the past half century, focus in research on social cognition (our ability to extract information about affects, drives, and intentions of our counterparts) has been shifted from traditional usage of static stimuli (primarily, photographs) to dynamic displays. Point-light movies of faces and bodies decrease the influence of other cues (such as gender, age, and other sources of structural information that may elicit certain perceptual biases) on our capacity for face and body reading.

Starting from the inspiring work of Canadian researcher John N. Bassili (1978, 1979), point-light dynamic faces (with a set of light dots placed on an invisible darkly-colored face) had been demonstrated to provide sufficient information not only for perceiving them as faces, but also for accurate facial affect recognition (e.g., Berry, 1990; Dittrich, 1991; Hill et al., 2003; Pollick et al., 2003; Atkinson et al., 2012; Bidet-Ildei et al., 2020; see also Dobs et al., 2018). Exaggeration of facial expressions relative to a neutral expression results in enhanced ratings of the emotion intensity, whereas changing the duration of an expression has a negligible effect on these ratings (Pollick et al., 2003). Distinct facial affect leads to different recognition levels, for example, angry facial expressions are recognized poorer than neutral or happy ones (Atkinson et al., 2012). Individuals with schizophrenia (SZ) can reliably recognize basic emotions (such as anger, fear, sadness, and happiness) from point-light faces, though they are less proficient than healthy controls (Tomlinson et al., 2006). Neurotypical perceivers can identify a speaker based on silent point-light facial information solely (Rosenblum et al., 1996; Jesse and Bartoli, 2018; Simmons et al., 2021), recognize emotions from visual-only point-light facial displays of singers (Quinto et al., 2014), and perform well not only on explicit but also on implicit facial affect recognition tasks (Bidet-Ildei et al., 2020). They also effectively use information in point-light displays when matching both unfamiliar and known faces (Bennetts et al., 2013). Already 7-month-old infants discriminate between angry and happy facial point-light expressions (Soken and Pick, 1992). Near-infrared spectroscopy (NIRS) shows that concentration of oxyhemoglobin (oxy-Hb) increases in the right temporal cortex of 5- to 8-month-old infants viewing point-light faces (Ichikawa et al., 2010; Ichikawa and Yamaguchi, 2012). Children aged 4 years recognize happy point-light faces, and 5–6-year-olds recognize a subtler facial expression of sadness (Doi et al., 2008). By 5 years of age, children reliably judge gender in point-light faces of persons engaged in interaction, though adults can also determine gender in faces reciting the alphabet (Berry, 1991).

Almost five decades ago, the point-light technique segregating perceptual signals available through body motion (BM) or *biological motion*, from other cues, had been introduced by the outstanding Swedish scholar from Uppsala University Gunnar Johansson (Johansson, 1973). A growing body of evidence shows that neurotypical individuals are rather competent in inferring emotions and dispositions of counterparts represented by point-light BM (e.g., Dittrich et al., 1996; Pollick et al., 2001; Atkinson et al., 2004; Heberlein et al., 2004; Clarke et al., 2005; Atkinson, 2009; Manera et al., 2010; Alaerts et al., 2011; Sokolov et al., 2011, 2020; Krüger et al., 2013; Actis-Grosso et al., 2015; Vaskinn et al., 2016). Effective body language reading is preserved in healthy aging, with particular tuning to displays portraying happiness (Spencer et al., 2016). Point-light gait can drive reliable judgments of personality traits such as approachability, neuroticism, trustworthiness, and warmth (Thoresen et al., 2012; see also Pavlova, 2012 on the Russian psychiatrist Pyotr B. Gannushkin who was reportedly able to recognize mental conditions of patients simply by observing their changing outline as they moved about in a dimly lit room).

Visual processing of BM and social cognitive abilities had been argued to be intimately tied (Pavlova, 2012). Indeed, individuals with neurodevelopmental and neuropsychiatric conditions (such as ASD, Williams-Beuren syndrome, and Down syndrome) and survivors of premature birth exhibiting aberrant processing of point-light BM also possess lower daily-life social competence (for reviews, see Pavlova, 2012; Pavlova and Krägeloh-Mann, 2013; Pavlova et al., 2021). Yet experimental data suggests that this association may be modulated by other factors such as gender (and age) as well as by methodological issues including task design and stimuli used. In earlier work of our group (Isernia et al., 2020), by using the same set of displays, i.e., identical visual input, task demands were directed either to body motion processing (determination of actors' gender) or emotion recognition. In males only, BM processing was found to be tightly connected with body language reading. Yet, in 8–11-year-olds, inter-correlations between four tasks (determination of a point-light walker's facing, detection of a point-light walker embedded into noise, labeling of actions of a stick moving figure, and person identification from moving style of a stick walking figure) are rather weak (Williamson et al., 2015), suggesting that diverse capabilities are engaged in performance.

Not only BM processing allies with body language reading, but effective body language reading buddies with other social skills. For example, both revealing identity of point-light dancers and estimations of emotional expression intensity correlate with self-reported empathy (Sevdalis and Keller, 2011, 2012). Confidence in emotion perception in point-light displays varies with the ability to perceive one's own emotions (Lorey et al., 2012). Body language reading ties not only with the more basic ability for discrimination between point-light canonical and scrambled BM displays, but also with accuracy on the Reading the Mind in the Eyes Test, RMET (Alaerts et al., 2011). In a sample of neurotypical adults predominated by females, efficiency of BM processing (such as facing detection of a point-light walker) is associated not only with performance on the RMET, but also with Autism Quotient (AQ), Empathy Quotient (EQ), and Cambridge Face Memory Test scores (Miller and Saygin, 2013). Even in children aged 7–12 years, BM detection is correlated with both reading in the eyes (as assessed by the RMET) and inferring of mental states based on understanding of stories (Strange Stories test; White et al., 2009), but performance on the RMET and Strange Stories test is not connected to each other (Rice et al., 2016). Therefore, in accord with earlier expectations (Pavlova, 2012), BM processing may be considered a basis for linking varied facets of social cognition. Curiously, even characteristics of social networks (such as a social network size defined as a number of peers heavily involved in daily communication) are reported to correlate with functional magnetic resonance imaging (fMRI) brain activation in response to point-light BM over key areas of the social brain such as the STS, superior temporal sulcus (Dziura and Thompson, 2014; Kirby et al., 2018).

Gender (a social construct) and sex (a neurobiological one) of observers are essential for performance on a wide range of social cognition tasks tapping bodies, faces, and eyes reading (Pavlova et al., 2010; Kret et al., 2011; Sokolov et al., 2011; Kirkland et al., 2013; Krüger et al., 2013; Pavlova et al., 2015, 2016, 2020; He et al., 2018, Dodell-Feder et al., 2020; Isernia et al., 2020; Kynast et al., 2021; see Pavlova and Sokolov, 2022b, for a most recent analysis of reading in the eyes). In the same vein, female but not male common marmosets (*Callithrix jacchus*) are reported to exhibit curiosity to point-light biological motion (Brown et al., 2010). Recently, gender/sex of observer is reported to affect reading covered faces, in particular, subtle emotional expressions (Carbon, 2020; Calbi et al., 2021; Grundmann et al., 2021; Proverbio and Cerri, 2022; for review, see Pavlova and Sokolov, 2022a). Magnetoencephalography (MEG) and fMRI reveal profound sex differences in the neural circuits underpinning point-light BM processing (Anderson et al., 2013; Pavlova et al., 2015; Jack et al., 2021). Females exhibit higher accuracy in recognition of point-light actions (such as jumping on the spot), and they are faster in discrimination of emotional from neutral locomotion (Alaerts et al., 2011). Yet gender differences in reading of body language (emotional locomotion and knocking on the door) are modulated by the portrayed emotion and actor gender (Sokolov et al., 2011; Krüger et al., 2013). Moreover, women surpass men in the recognition of neutral knocking (Sokolov et al., 2011). In females, but not males, body language reading is associated with mindreading in the eyes (Isernia et al., 2020). As pointed out earlier (Pavlova, 2012, 2017a,b; Duchesne et al., 2020), gender/sex impact can be of substantial value not only for a better conceptualization of social cognition, but also for understanding neuropsychiatric conditions most of which are gender/sex-specific.

Covering faces with masks leaves a comparable amount of visual information for face reading as the RMET (a set of photographs of a pair of eyes along with the surrounding part of a face including hairstyle; Pavlova and Sokolov, 2022a,b; **Figure 1**) does. Most recent experimental work indicates that RMET performance predicts accuracy of facial affect recognition of masked faces (Swain et al., 2022). Clarifying the issue of how masks affect face reading in real life, where we deal with dynamic faces and have *entrée* to additional social signals such as body language, warrants rigorous experimental work (Pavlova and Sokolov, 2022a). In real life, we usually cope with plentiful and often redundant social information that helps to prevent paying high costs for maladaptive or misleading social interaction. It was shown, for example, that the influence of face masks on recognition of emotions (anger, happiness, sadness, and fear) is diminished (or even negligible) when static whole body is present (Ross and George, 2022). Moreover, as the lack of information from masked faces may be compensated by other sources such as dynamic bodies, it is worthwhile to study whether, and, if so, how the abilities for face, body, and eyes reading are connected to each other.

In the present work, we examined: (i) whether the abilities for reading of dynamic faces and bodies are intimately tied; (ii) whether, and, if so, how, this link is gender-specific; and (iii) whether face reading and body reading are related to other social skills such as reading language of the eyes. Based on the outcome of earlier work (e.g., Miller and Saygin, 2013; Gökçen et al., 2014; Baltazar et al., 2021), we expected that efficiency of body, face, and eyes reading will be related to autistic traits expression. Neurotypical females and males accomplished a body language reading task along with a face reading task. They had to infer emotional content of displays. Furthermore, participants were administered the Reading the Mind in the Eyes Test, Modified (RMET-M) and Autism Quotient (AQ) questionnaire.

Materials and methods

Participants

Fifty participants (26 females and 24 males; aged 19–31 years) were involved in the study. The data set of one male

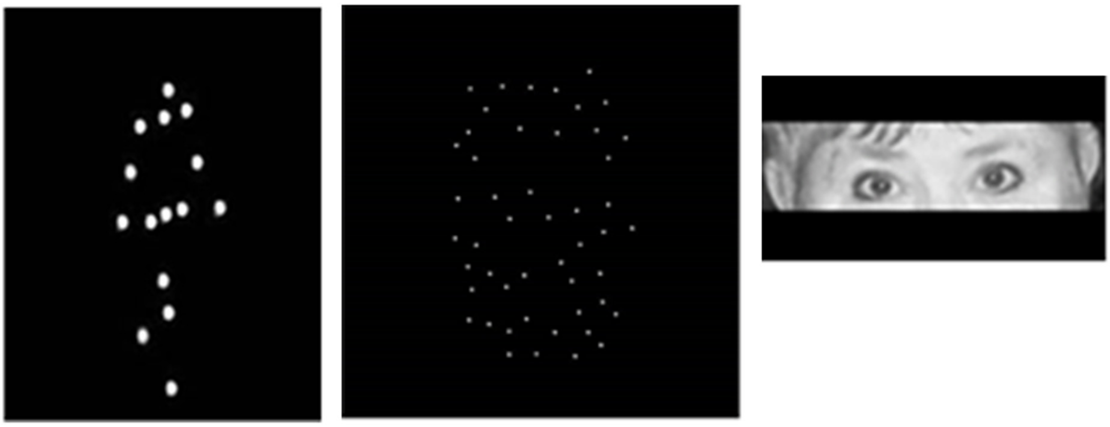

FIGURE 1
Illustration of stimuli used. From left to right: a static frame from dynamic sequence exemplifying locomotion as a set of dots placed on the main joints and a head of an invisible actor (a walking person is seen facing right in intermediate position between the frontal and sagittal views); a frame from dynamic sequence representing a point-light face of a female actor expressing anger; illustration of stimuli used for studying reading in the eyes [From Pavlova and Sokolov (2022a) with permission of Oxford University Press, and permission and written agreement of the poser].

participant was excluded from further data processing, since he turned out to have a history of psychiatric conditions. This left the data of 49 (23 males) participants. None of them had head injuries, a history of neuropsychiatric disorders (including ASD, SZ, and depression), or regular drug intake (medication). Males were aged 26.13 ± 2.96 years (mean ± standard deviation, SD), and females 24.96 ± 3.5 years ($t(47) = 0.81$, $p = 0.212$, two-tailed, n.s.). As performance on the RMET-M (German version, modified; for details, see below) requires language command of high proficiency, German as native language was used as one of the inclusion criteria. All observers had normal or corrected-to-normal vision. Participants were tested individually, and were naïve as to the purpose of the study. None had previous experience with such displays and tasks. The study was conducted in line with the Declaration of Helsinki and approved by the local Ethics Committee at the University of Tübingen Medical School. Informed written consent was obtained from all participants. Participation was voluntary, and the data sets were processed anonymously.

Face reading: Point-light faces

For this task (inferring of emotions from face motion, face-motion-emotion, FME), participants were presented with a set of point-light black-and-white animations portraying face motion of female and male protagonists expressing happiness and angriness. Display production is described in detail elsewhere (Atkinson et al., 2012). The stimuli were kindly shared with us by Dr. Anthony Atkinson. In brief, 50 small white dots were positioned in a quasi-random order on an actor face. To ensure an even distribution of the dots, the face was divided into four quadrants, with the tip of the nose as a center, where two imaginary lines, horizontal and vertical, met. Each quadrant contained approximately the same number of white dots. The quasi-random placement minimized availability of structural information, such as from areas of the lips, cheeks or eyebrows. No dots were placed on the eyelids. Still, some static form cues could not be prevented such as dark regions at the position of eyes and a mouth's opening. The displays had been proven for recognizability in behavioral and neuroimaging studies (e.g., Atkinson et al., 2012).

The videos of 6 (3 female/3 male) actors with happy and angry expressions were presented in 3 separate runs with a short break between them. In total, each experimental session consisted of a set of 108 trials (6 actors [3 female/3 male] × 2 emotions [happy/angry] × 3 displays for each emotion by each actor × 3 repetitions of each stimulus). In a two-alternative forced choice (2AFC) paradigm, participants had to indicate (by pressing one of two respective keys) facial affect (happy or angry). Each video lasted 2 s. Participants were asked to respond right after stimulus offset. During an inter-stimulus interval (ISI; after stimulus offset till onset of the next stimulus right after participant's response) that was randomly jittered between 3 and 5 s, a white fixation cross was displayed in the center of the screen. If participants failed to respond within this period, the next trial started automatically.

Body language reading: Point-light locomotion

For inferring of emotion from point-light BM, body-motion-emotion (BME) task, participants were presented with a set of point-light black-and-white animations portraying human locomotion. Display production is described in detail elsewhere (Ma et al., 2006; Krüger et al., 2013). The displays were built up by using the Motion Capture Library (N Stage, Pinewood Studios, Iver Heath, Buckinghamshire, United Kingdom). In brief, recording was performed using a 3D position measurement system at a rate of 60 Hz (Optotrak, Northern Digital Inc., Waterloo, ON, Canada). The matrix data for each frame was processed with MATLAB (The Mathworks Inc., Natick, MA, United States) into a video sequence. Each display consisted of 15 white dots visible against a black background (**Figure 1**). The dots were placed on the shoulder, elbow, and wrist of each arm; on the hip, knee, and ankle of each leg; and on the head, neck, and pelvis of a body. As we intended to make tasks demanding and expected more pronounced effects with brief stimulus duration, each movie lasted for 2 s that corresponded to one walking cycle consisting of two steps. During locomotion, a walker was seen facing right in the intermediate position of 45° between the frontal and sagittal views. As the sagittal view is often considered neutral in respect to possible social interactions, and the frontal view is reported to elicit ambiguous (facing either backward or toward an observer) and often gender-dependent impressions of locomotion direction (Pollick et al., 2005; Brooks et al., 2009; Schouten et al., 2010, 2011), the intermediate trajectory of locomotion was used. For creation of left-facing stimuli, we rotated the videos to 90° horizontally. The walking figure was pelvis-fixed to the middle of the screen. Female and male actors walked either with angry or neutral expression. For avoiding variability in emotion portrayal, several sets of neutral and angry stimuli were produced from the same actors.

The stimuli were selected from a previous study of our group (Isernia et al., 2020): we excluded movies of one female and one male actor that were the least recognizable ones. As a result, the videos of 4 (2 female/2 male) actors facing either right or left were presented in 3 separate runs with a short break between them. In total, each experimental session consisted of a set of 144 trials (4 actors [2 female/2 male] × 2 emotions [neutral/angry] × 2 facing directions [left/right] × 9 [3 repetitions of each stimulus × 3 runs]). Participants were asked to respond upon each stimulus offset. In a 2AFC paradigm, participants had to indicate by pressing one of two respective keys the emotional content of locomotion (angry/neutral). During an ISI (after stimulus offset till onset of the next stimulus right after the participant's response) that randomly varied between 3 and 5 s, a white fixation cross was displayed in the center of the screen. If the participant failed to respond within this period, the next trial started automatically.

Reading the Mind in the Eyes Test, modified

A computer version of the RMET-M (M, modified) was additionally administered to all participants. This test is described in detail elsewhere [Baron-Cohen et al., 2001a; see also most recent analysis by Pavlova and Sokolov (2022b)]. In brief, the original standard version of the RMET consists of 36 black-and-white photographs of female and male eyes along with a corresponding face part expressing a certain emotional or affective state. On each trial, participants had to choose among four alternative descriptions (adjectives simultaneously presented on the screen) including the correct one that corresponded with the image. We modified the RMET German version in such a way that, first of all, it did not as heavily rely on language capabilities as the standard one. To this end, instead of four adjectives we used only two of them (one correct and one incorrect). For example, for the item with four response options [besorgt/alarmed (correct) – ernst/serious – beschämt/ashamed – verblüfft/bewildered (all three incorrect)], we chose [besorgt (correct) – ernst (incorrect)]. This also led to shortening decision making time and, respectively, response time, which is of importance for MEG recording with patients at a later time point. Second, we selected 16 photographs out of original 36 to make the set of stimuli balanced in respect to the number of (i) female and male photographs (8 female/8 male), and (ii) positive and negative affective expressions (8 positive/8 negative). In addition, on the basis of our previous research with the standard RMET version (Isernia et al., 2020), we selected the photographs on which reading in the eyes was most difficult in order to retain individual variability. Each experimental session consisted of 80 trials (16 photographs × 5 repetitions) presented in a pseudorandomized order. Each image was exposed for 2 s. Then two words (correct and incorrect responses) appeared on the right and left sides of a black screen. Participants were asked to respond as accurately but also as fast as possible upon stimulus offset (with a time limit of 12 s). After each response, during an ISI that randomly varied between 2 and 3 s, a white fixation cross was displayed in the center of the screen. If participants failed to respond, the next trial started automatically. The whole experimental session (consisting of all three tasks: body reading, face reading, and the RMET-M) took about 40–45 min per participant. For all three tasks, no immediate feedback was given regarding performance.

Autism quotient questionnaire

The AQ questionnaire for ages 16 and up, developed by Simon Baron-Cohen and colleagues (Baron-Cohen et al., 2001b), is intended to assess the expression of autistic traits by self-estimation. The questionnaire comprises 50 items, or statements, such as "*I prefer to do things with others rather than* *on my own*." For each statement, participants have to indicate how strongly that statement applies to her or him using four response options "*Definitely agree – Agree – Disagree – Definitely disagree*." The maximal score of autistic traits expression is 50. Yet the response to each statement (item) is then scored in a binary fashion (either 0 or 1). The items with positive (agreement) or negative (disagreement) responses are balanced in the AQ questionnaire. The statements intend to cover five domains characterizing autistic traits expression, including social competence, attention shifting, and focus on detail. In the present study, the AQ questionnaire version psychometrically evaluated and adapted to the German population had been used (Freitag et al., 2007). Some statements of the AQ do not take into account changes in preferences elicited by aging or educational status rather than by personality traits. For instance, for the statement "*I would rather go to the library than to a party*," older people as well as persons with higher educational status are generally more likely to provide a positive response than the youth and people with lower educational status. The present study comprises a rather homogenous group of students of comparable age and education, and, therefore, these factors are unlikely to affect their response choices.

Data analysis

Inferential data processing was performed by using JMP software (version 13; SAS Institute; Cary, North Carolina, United States.). All data sets were first routinely assessed for normality of distribution by Shapiro-Wilk tests with subsequent uses of either parametric (such as analysis of variance, ANOVA, Student *t*-test, Pearson product moment correlation) for normally distributed data or, otherwise, non-parametric (such as Mann–Whitney *U*-test, Spearman rank correlation) statistics. For not normally distributed data sets, additionally to means and SDs, medians (Mdns) and 95% confidence intervals (CIs) are reported throughout the text.

Results

Face and body language reading

Individual rates of correct responses on both dynamic point-light tasks (inferring emotions either from face motion, FME, or from body motion, BME) were submitted to a mixed model 2 × 2 repeated-measures ANOVA with a within-subject factor Task (FME/BME) and a between-subject factor Observer Gender (female/male). The outcome revealed a main effect of Task ($F(1;48) = 423.64$, $p < 0.001$, effect size, *eta squared* $\eta^2 = 0.815$; with greater accuracy on revealing emotions from dynamic faces than bodies) and a significant Task × Observer Gender interaction ($F(1;48) = 40.65$, $p = 0.047$, effect size, $\eta^2 = 0.297$; with greater accuracy of females on the BME task and no gender difference on the FME task). The main effect of Observer Gender was non-significant ($F(1;48) = 12.82$, $p = 0.26$, n.s.). *Post hoc* analysis (using Tukey honestly significant difference, HSD, tests) indicated a lack of gender differences in accuracy of face reading (FME task: 0.74 ± 0.09 for females, 0.76 ± 0.07 for males; $t(47) = 0.71$, $p = 0.479$, n.s., all tests corrected for multiplicity), but an advantage of females on body reading (BME task: 0.67 ± 0.07 for females, 0.62 ± 0.09 for males; $t(47) = 2.54$, $p = 0.014$; effect size, Cohen's $d = 0.625$). Females were also faster on correct responses in both tasks [FME: for females, 0.670 ± 0.261 s (Mdn, 0.574 s, 95% CI, from 0.570 to 0.770 s); and for males, 0.812 ± 0.259 s; Mann–Whitney test, $U = 195$, $p = 0.039$, two-tailed, effect size, $d = 0.624$; BME: for females, 0.580 ± 0.196 s, and for males, 0.759 ± 0.196 s; $t(47) = 3.23$, $p = 0.002$, two-tailed; effect size, $d = 0.913$].

Most important for the purpose of the present work, face and body language reading were related to each other in a gender-specific manner. In females, accuracy of inferring emotions through point-light face (FME task) and body (BME task) were positively linked (Pearson product moment correlation, $r(24) = 0.438$, $p = 0.025$; effect size, Cohen's $q = 0.47$), whereas no such association occurred in males ($r(21) = 0.025$, $p = 0.91$, n.s.; **Figure 2**). In females, also processing speed (correct response time) of face and body language reading were strongly allied with each other (Spearman's rho, $\rho(24) = 0.759$, $p < 0.001$, effect size, $q = 0.994$), though this link occurred also in males ($r(21) = 0.830$, $p < 0.001$, effect size, $q = 1.188$; **Figure 3**).

Link of face and body reading with reading in the eyes

The RMET-M was administered for addressing the issue of whether face reading and body language reading are connected to other social cognitive abilities such as reading in the static eyes. Based on earlier reports with the standard RMET (e.g., Kirkland et al., 2013; Baron-Cohen et al., 2015; Dodell-Feder et al., 2020; Kynast et al., 2021; for recent review, see Pavlova and Sokolov, 2022b) including the recent work of our own group (Isernia et al., 2020), we anticipated females to be more proficient on the RMET-M. Contrary to our expectations, however, accuracy of females and males was comparable (0.77 ± 0.10 for females, and 0.75 ± 0.09 for males; $t(47) = 0.19$, $p = 0.288$, one-tailed). Yet females surpassed males in processing speed, responding much faster (for females, 1.969 ± 0.390 s (Mdn, 1.949 s, 95% CI, from 1.819 to 2.119 s), for males, 2.236 ± 0.368 s; $U = 185$, $p = 0.023$, two-tailed; effect size, $d = 0.69$). Most startling within the framework of the present study is the outcome indicating that reading in the static eyes is gender-specifically related

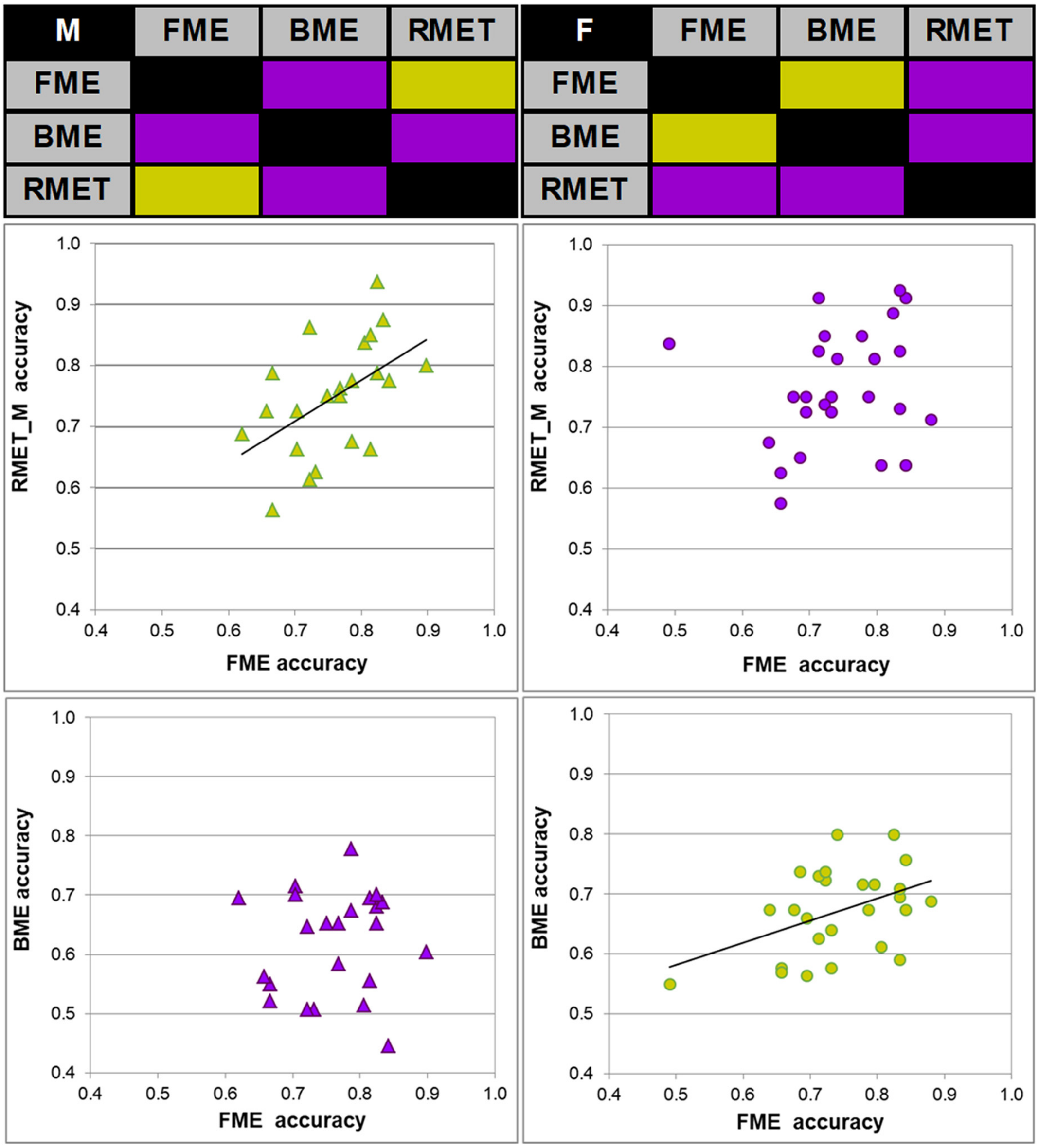

FIGURE 2
Links between accuracy of face and body reading through point-light biological motion, and performance on the Reading the Mind in the Eyes Test, modified (RMET-M), for female and male participants. Correlation matrices between accuracy of performance (correct response rate) on inferring emotions from faces (FME), bodies (BME), and the RMET-M for males (top left) and females (top right). Significant correlations (Pearson product moment correlations, two-tailed; $p < 0.05$) are color-coded by green, non-significant correlations by violet. Correlations between the FME and RMET accuracy in males (left middle panel, green diamonds) and between the FME and BME accuracy in females (right bottom panel, green circles) were significant.

to reading dynamic faces. In males, accuracy on both tasks correlated with each other ($r(21) = 0.506$, $p = 0.014$; effect size, $q = 0.557$), whereas such bond was absent in females ($r(24) = 0.195$, $p = 0.340$, n.s.; Figure 2). Similarly, processing speed (as measured by correct response time) correlated between the RMET-M and FME tasks in males ($r(21) = 0.450$, $p = 0.03$; effect size, $q = 0.485$; Figure 3), but not in females ($\rho(24) = 0.341$, n.s.).

Based on earlier work (Alaerts et al., 2011; Miller and Saygin, 2013; Isernia et al., 2020), we expected to find a positive tie between accuracy of body language reading and mindreading in the eyes as measured by the RMET-M, at least, in female participants. Yet in both females and males, correlations between recognition accuracy on these tasks turned out to be non-significant (for females, $r(24) = 0.235$, $p = 0.248$; for males, $r(21) = 0.207$, $p = 0.343$, n.s.). Yet correct response time on

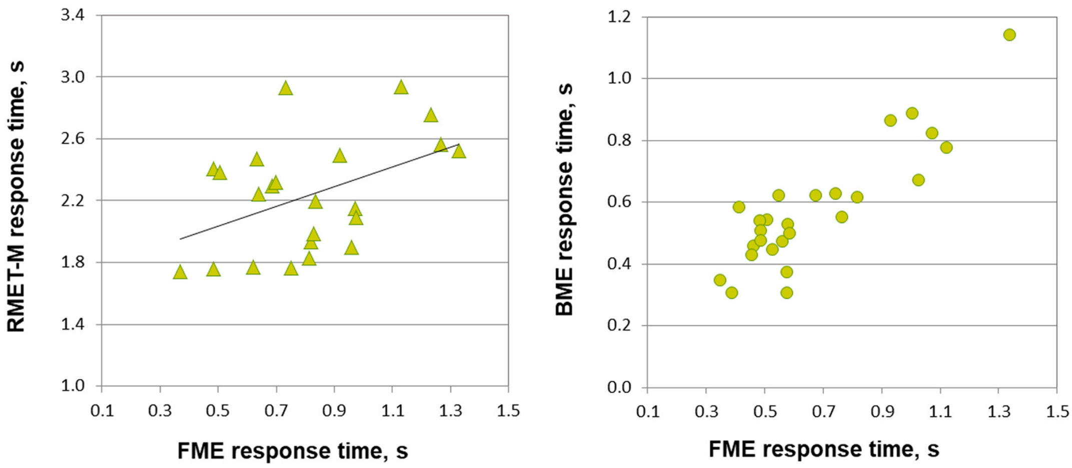

FIGURE 3
Relationship between response time on emotion through face motion (FME), body motion (BME) tasks, and RMET-M for female and male participants. In males (left panel, triangles), response time for correct responses on the FME task correlates with response time on the RMET-M (Pearson correlation). In females (right panel, circles) response times of correct responses on the FME and BME tasks correlate with each other (Spearman correlation, $p < 0.001$).

the RMET-M and BME tasks correlated with each other both in females ($\rho(24) = 0.420$, $p = 0.003$; effect size, $q = 0.448$) and in males ($r(21) = 0.607$, $p = 0.002$; effect size, $q = 0.704$).

Link of face, body, and eyes reading with autistic traits

In our sample of neurotypical individuals, the AQ scores were in the range from 4 to 25 (15.26 ± 3.97) for males and from 8 to 21 (12.93 ± 4.77) for females. Males exhibited a tendency for higher autistic traits expression than females ($t(47) = 1.52$, $p = 0.067$; two-tailed). Most important, in accord with our expectations, albeit in males only, the AQ scores negatively correlated with accuracy on the BME task ($r(21) = -0.415$, $p = 0.024$, one-tailed; effect size, $q = 0.442$) as well as on the RMET-M ($r(21) = -0.593$, $p = 0.002$, one-tailed; effect size, $q = 0.682$), whereas the negative link between the AQ scores and accuracy on the FME task only tended to reach significance ($r(21) = -0.349$, $p = 0.052$). Yet in females, correlations between the AQ scores and performance on all three tasks were non-significant (FME, $r(24) = -0.105$, $p = 0.313$, n.s.; BME, $r(24) = 0.080$, $p = 0.355$, n.s.; RMET-M, $r(24) = 0.084$, $p = 0.347$, n.s.).

Discussion

This work was directed at the proof of concept according to which reading faces is tied with body language reading. Keeping in mind evidence for gender-specific modes in social cognition, we focused primarily on gender specificity of this link. The findings reveal that: (i) Females excel on inferring emotions from body locomotion, but not from dynamic faces. Moreover, in females only, body language reading and face reading are firmly linked. (ii) In turn, in males only, face reading is related to reading in the eyes. The outcome points to gender-specific modes in social cognition: females primarily rely upon dynamic cues in facial and bodily displays, whereas males most likely trust configural information revealed through motion.

The findings provide support for the general concept according to which efficiency of BM processing may serve a hallmark of social cognition (Pavlova, 2012). Earlier work pointed to a tie between BM processing and social cognition: individuals with aberrant BM processing also possess lower social competence, empathy, and face recognition capabilities (Sevdalis and Keller, 2011; Miller and Saygin, 2013). Our previous study (Isernia et al., 2020) was designed to untangle the ties between BM and body language reading by using strictly identical visual input and re-directing task demands either to BM processing (gender decoding based on revealing biomechanical characteristics of locomotion; Kozlowski and Cutting, 1977; Barclay et al., 1978; Cutting et al., 1978; Pollick et al., 2005) or to inferring emotions. We uncovered gender specificity of this link: males only rely upon common mechanisms supporting gender and emotion recognition through BM (Isernia et al., 2020).

Link between reading bodies and faces

The present work helps to untangle ties between body language reading and other social cognitive abilities. For the first time, we asked whether face and body reading skills are linked. In females only, a strong association was found between body language and face reading (in terms of both accuracy and processing speed), whereas in males, processing speed (but not accuracy) of dynamic point-light faces and bodies were related to each other.

Already the developing brain is tuned to dynamic faces and bodies. As indicated by functional NIRS, in human infants aged 7–8 months, point-light faces elicit increased concentration of oxy-Hb in the right brain hemisphere (Ichikawa et al., 2010). Event-related potentials indicate that infants aged 8 months have a larger positive amplitude in the right parietal regions at latencies between 200 and 300 ms when passively viewing upright point-light BM as compared with inverted stimuli (Reid et al., 2006). Of note, a right hemispheric dominance in BM processing has been suggested already in newborn chicks (Rugani et al., 2015). Facial muscular activity alters the recognition of both facial and bodily expressions (Marmolejo-Ramos et al., 2020). Yet little is known about communication of the neural networks underpinning reading dynamic faces and bodies. As to our knowledge, the only brain imaging study investigated the relationship between reading of point-light faces and bodies in the same cohort of participants (Atkinson et al., 2012): In neurotypical adults (N = 17/9 females), no difference in fMRI activation elicited either by reading faces or bodies was found in the left fusiform body area (FBA) and right STS, where substantial topographical overlap occurred between face- and body-selective areas.

By contrast with women, men appear to bank primarily on structural information revealed by motion of point-light faces. Accuracy and processing speed of reading dynamic point-light faces is tightly interconnected with the reading the mind in the static eyes as measured by the RMET-M. The link in performance between these tasks is absent in females. In addition, we did not find overperformance of females on the RMET-M [in contrast to other studies conducted with the standard RMET (Baron-Cohen et al., 2001a, 2015; Schiffer et al., 2013; Baron-Cohen, 2017; Megías-Robles et al., 2020; Kynast et al., 2021), including our own findings (Isernia et al., 2020)]. This discrepancy most likely can be explained by modifications to the standard version (see Methods section), in contrast to which the RMET-M does not heavily rely on language capabilities and is balanced in relation to the visual input. Contrary to common beliefs about female superiority on social cognition tasks (cf. Sokolov et al., 2011; Krüger et al., 2013), females did not overperform males not only on the reading through the static eyes, but also on reading point-light faces. Yet, females were better in reading point-light body language. No gender differences on a similar task were found in our previous study (Isernia et al., 2020), presumably because for the present study, the task had been modified (see Methods section).

The present study was conducted in a student sample of young adults that affords group homogeneity. Although such a population is commonly used in the field, this may represent a limitation in terms of the outcome generalizability.

Underpinning brain networks

Brain imaging of point-light BM processing as well as detection of social interaction in Heider-and-Simmel-like animations suggests existence of gender-specific modes in brain processing of socially relevant information even in the absence of behavioral differences: gender/sex-related dimorphism may prevent behavioral differences if they are maladaptive (Pavlova et al., 2010, 2015). Likewise, differences in neural networks might contribute to the lack of gender differences in reading of the static eyes and dynamic faces in the present study. Detailed clarification of this issue calls for tailored brain imaging work.

Reading dynamic faces and bodies as well as reading in the eyes rely on the large-scale neural ensembles constituting the social brain with such topographically overlapping nodes as the face fusiform area (FFA), STS, and insula primarily in the right hemisphere (Atkinson et al., 2012; Grosbras et al., 2012; Engell and McCarthy, 2013; Dasgupta et al., 2017). For understanding a proper functioning of this network and its pathology, one has to consider changes in brain activation unfolding over time (Pavlova, 2017a). Ultra-high-field 9.4T fMRI along with a temporal analysis of blood oxygen level-dependent (BOLD) dynamics, reveals distinct large-scale ensembles playing in unison during different stages of body motion processing (Pavlova et al., 2017). Furthermore, an integrative analysis of structural and effective brain connectivity during point-light BM detection sheds light on architecture and functional principles of the neural circuitry which is organized in a parallel rather than hierarchical way: BM detection is best predicted by functional communication (effective connectivity) and presence of white-matter pathways between the right STS and fusiform gyrus (Sokolov et al., 2018). Research on the brain networks dedicated to body language reading is sparse (Heberlein et al., 2004; Atkinson et al., 2012; Jastorff et al., 2015; Mazzoni et al., 2017; He et al., 2018). By using cutting-edge analyses of effective brain connectivity, the brain networks differentiating neutral and emotional body language had been revealed: the right amygdala and midline cerebellar vermis are profoundly engaged in non-emotional as compared to emotional body language reading, and the effective connectivity between these brain structures predicts the ability to detect the absence of emotion (Sokolov et al., 2020).

This outcome opens a window for studying emotional interpretation of social signals in ASD by providing the missing connection between body language reading and limbic pathways.

Link between autistic traits and reading bodies, faces, and eyes

Arrestingly, in males solely, reading dynamic faces and bodies as well as reading in the eyes are inversely knotted with autistic traits. By contrast, these links are absent in females. (i) *Autistic traits and the RMET.* As to our knowledge, the present study is the first to report the gender specificity of a negative link between reading in the eyes and autistic traits expression. The RMET had been developed for studying some aspects of social cognition in autism (Baron-Cohen et al., 1997, 2001a, 2015; Baron-Cohen, 2017; for recent review, see Pavlova and Sokolov, 2022b), and the most replicable and robust finding is that individuals with ASD exhibit lower RMET scoring (Del Valle Rubido et al., 2018; Peñuelas-Calvo et al., 2019; Baltazar et al., 2021). In the neurotypical population, the RMET scores are also lower in individuals with higher autistic traits expression (Gökçen et al., 2014). (ii) *Autistic traits and body language reading.* Mounting evidence points to alterations of both BM processing and affective body language reading in ASD (Hubert et al., 2007; Freitag et al., 2008; Atkinson, 2009; Klin et al., 2009; Kaiser et al., 2010; Nackaerts et al., 2012; Pavlova, 2012; Centelles et al., 2013; Mazzoni et al., 2020, 2021; Jack et al., 2021; Sotoodeh et al., 2021; for review, see Pavlova, 2012; Barton, 2021), though intact BM processing is also reported (Murphy et al., 2009). Most important, the sensitivity to BM is inversely linked both to the severity of ASD (Blake et al., 2003) and to autistic symptomatology as measured by the autistic diagnostic observation schedule (ADOS) in adolescents (Koldewyn et al., 2010). BM perception and its development may be predictable by intelligence quotient, IQ (Rutherford and Troje, 2012; Mazzoni et al., 2020). Moreover, emotion recognition in BM is reported to be not generally impaired in a sample of high-functioning (with IQ within or higher than the normal range) autistic individuals predominated by males: some emotions are recognized much better than others (Actis-Grosso et al., 2015). In ASD, some difficulties are reported also in interpreting E-Motions, i.e., affective expressions conveyed either by static faces or body postures with a high degree of perceived dynamics, forces at work (Della-Torre et al., 2021). Individuals with a high degree of autistic traits expression exhibit deficits in identifying whole-seen own body motion (Burling et al., 2019). In a sample of adults predominated by females (N = 57/16 males), a negative association is found between autistic traits and detection of a point-light walker's facing (Miller and Saygin, 2013). In the same-sex twins aged 15–27 years, perception of local point-light BM (motion of single elements) rather than a global configuration is connected with heritable autistic traits (Wang et al., 2018). Yet, rather paradoxically, in preterm-born children aged 8–11 years, autistic traits are positively correlated with the ability to determine identity of walkers represented by locomotion of stick figures (Williamson et al., 2015). In neurotypical adults (N = 12/7 males) pooled together with autistic individuals (N = 12/7 males), emotion recognition through BM is reported to be knotted with scoring on the Social Responsiveness Scale (SRS, serving for detection of autistic symptoms) as well as with BM processing, and discrimination between canonical and scrambled walkers (Nackaerts et al., 2012). Here, for the first time, we report not only the negative link between emotional dynamic body language reading and autistic traits expression, but also gender specificity of this tie. (iii) *Autistic traits and face reading.* Finally, for the first time, we show the negative bond between reading of point-light dynamic faces and autistic traits expression, underscoring its gender specificity.

Notably, autism is well-known for its skewed gender/sex ratio: males are affected more often, with a ratio of about 4:1 or even greater (Hull et al., 2020; Maenner et al., 2020). Moreover, females and males are affected differently in terms of clinical picture, prevalence, and severity (Pavlova, 2012, 2017b). Female ASD is understudied, and, therefore, certain caution is needed in drawing conclusions based on male-predominant cohorts. Neurobiological mechanisms of the greater prevalence of affected males are largely unknown, though the *female protective effect* is thought to stem from a genetic predisposition for ASD, differentially impacting the female brain. Most recently, it is reported that genetic load for ASD affects functional connectivity of the salience network [the midcingulo-insular network (M-CIN), a large-scale brain network primarily composed of the anterior insula (AI) and dorsal anterior cingulate cortex (dACC) that contributes to a variety of complex functions, including social behavior, through the integration of sensory and emotional input] in boys (8–17 years old) but not in girls with and without ASD (Lawrence et al., 2020). This outcome suggests that risk genes for ASD intermingle with sex-differential processes, thereby contributing to the male bias in autism prevalence.

Résumé

For achieving efficient social interaction during the COVID-19 pandemic, we are forced to combine social signals from different sources such as the eyes (with a face hidden behind a mask) and bodies. The present work was directed at the proof of concept according to which face reading is intimately tied with body language reading. The outcome reveals that: (i) Females excel at inferring emotions from body locomotion, but not from dynamic faces. Moreover, in females only, body reading and face reading are firmly linked; (ii) In turn, in males only, face reading is closely related to reading in the eyes as assessed by the modified version of the RMET, RMET-M. The outcome points to gender-specific modes in social cognition: females primarily rely upon dynamic cues in facial and bodily displays, whereas males most likely trust configural information revealed through motion. Arrestingly, in males solely, reading of dynamic faces, bodies, as well as reading in the static eyes are all inversely knotted with autistic traits expression. The findings are of importance for examination of face and body language reading in neuropsychiatric conditions, in particular, ASD, most of which are gender-specific. Tailored brain imaging research is required to clarify to what extent face, body language, and eyes reading share topographically and dynamically overlapping neural networks. This may be of particular value in light of the current COVID-19 pandemic. Mandatory covering faces with medical masks may lead to difficulties in social cognition and interaction (Pavlova and Sokolov, 2022a,b). As people are unable anymore to rely on the habitual information, they need to pick and pool together social signals from different sources such as eyes and bodies. In this connection, revealing bonds between reading faces, bodies and mindreading in the eyes, as well as their gender specificity is of particular value. The present work suggests that if males with autistic traits experience difficulties in reading covered with masks faces, these deficits may be unlikely compensated by reading (even dynamic) bodies and faces. By contrast, in females, reading covered faces as well as reading language of dynamic bodies and faces are not compulsorily connected to autistic traits preventing them from paying high costs for maladaptive social interaction.

Data availability statement

The data supporting the conclusions of this article are either included in the article or will be made available by the authors upon request to any qualified researcher.

Ethics statement

The study protocols involving human participants were reviewed and approved by the Ethics Committee at the University of Tübingen Medical School. Participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MAP conceived and designed the study, wrote the manuscript, and supervised the whole project. SI, VR, and JK contributed to stimuli creation and programming of experiments. VR, JK, and ANS performed the experiments and collected data. MAP and ANS analyzed the data and created figures. MAP and AJF contributed reagents, materials, and analysis tools. All co-authors contributed to the writing and editing of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Actis-Grosso, R., Bossi, F., and Ricciardelli, P. (2015). Emotion recognition through static faces and moving bodies: a comparison between typically developed adults and individuals with high level of autistic traits. *Front. Psychol.* 6:1570. doi: 10.3389/fpsyg.2015.01570

Alaerts, K., Nackaerts, E., Meyns, P., Swinnen, S. P., and Wenderoth, N. (2011). Action and emotion recognition from point light displays: an investigation of gender differences. *PLoS One.* 6:e20989. doi: 10.1371/journal.pone.0020989

Anderson, L. C., Bolling, D. Z., Schelinski, S., Coffman, M. C., Pelphrey, K. A., and Kaiser, M. D. (2013). Sex differences in the development of brain mechanisms for processing biological motion. *Neuroimage* 83, 751–760. doi: 10.1016/j.neuroimage.2013.07.040

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., and Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception* 33, 717–746. doi: 10.1068/p5096

Atkinson, A. P., Vuong, Q. C., and Smithson, H. E. (2012). Modulation of the face- and body-selective visual regions by the motion and emotion of point-light face and body stimuli. *Neuroimage* 59, 1700–1712. doi: 10.1016/j.neuroimage.2011.08.073

Atkinson, A. P. (2009). Impaired recognition of emotions from body movements is associated with elevated motion coherence thresholds in autism spectrum disorders. *Neuropsychologia* 47, 3023–3029. doi: 10.1016/j.neuropsychologia.2009.05.019

Baltazar, M., Geoffray, M. M., Chatham, C., Bouvard, M., Martinez Teruel, A., Monnet, D., et al. (2021). "Reading the Mind in the Eyes" in autistic adults is modulated by valence and difficulty: An InFoR Study. *Autism Res.* 14, 380–388. doi: 10.1002/aur.2390

Barclay, C. D., Cutting, J. E., and Kozlowski, L. T. (1978). Temporal and spatial factors in gait perception that influence gender recognition. *Percept Psychophys.* 23, 145–152. doi: 10.3758/bf03208295

Baron-Cohen, S., Bowen, D. C., Holt, R. J., Allison, C., Auyeung, B., Lombardo, M. V., et al. (2015). The "Reading the Mind in the Eyes" Test: Complete Absence of Typical Sex Difference in ˜400 Men and Women with Autism. *PLoS One* 10:e0136521. doi: 10.1371/journal.pone.0136521

Baron-Cohen, S., Jolliffe, T., Mortimore, C., and Robertson, M. (1997). Another advanced test of theory of mind: Evidence from very high functioning adults with autism or Asperger syndrome. *J. Child Psychol. Psychiatry* 38, 813–822. doi: 10.1111/j.1469-7610.1997.tb01599.x

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001a). The "Reading the Mind in the Eyes" test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *J. Child. Psychol. Psychiatry* 42, 241–251. doi: 10.1111/1469-7610.00715

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., and Clubley, E. (2001b). The autism-spectrum quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *J. Autism Dev. Disord.* 31, 5–17. doi: 10.1023/a:1005653411471

Baron-Cohen, S. (2017). The eyes as window to the mind. *Am. J. Psychiatry.* 174, 1–2. doi: 10.1176/appi.ajp.2016.16101188

Barton, J. J. S. (2021). Motion perception and its disorders. *Handbook Clin. Neurol.* 178, 257–275. doi: 10.1016/B978-0-12-821377-3.00013-1

Bassili, J. N. (1978). Facial motion in the perception of faces and of emotional expression. *J. Exp. Psychol.* 4, 373–379. doi: 10.1037//0096-1523.4.3.373

Bassili, J. N. (1979). Emotion recognition: the role of facial movement and the relative importance of upper and lower areas of the face. *J. Pers. Soc. Psychol.* 37, 2049–2058. doi: 10.1037/0022-3514.37.11.2049

Bennetts, R. J., Kim, J., Burke, D., Brooks, K. R., Lucey, S., Saragih, J., et al. (2013). The movement advantage in famous and unfamiliar faces: a comparison of point-light displays and shape-normalised avatar stimuli. *Perception* 42, 950–970. doi: 10.1068/p7446

Berry, D. S. (1990). What can a moving face tell us? *J. Pers. Soc. Psychol.* 58, 1004–1014. doi: 10.1037/0022-3514.58.6.1004

Berry, D. S. (1991). Child and adult sensitivity to gender information in patterns of facial motion. *Ecol. Psychol.* 3:349. doi: 10.1207/s15326969eco0304_3

Bidet-Ildei, C., Decatoire, A., and Gil, S. (2020). Recognition of emotions from facial point-light displays. *Front. Psychol.* 11:1062. doi: 10.3389/fpsyg.2020.01062

Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., and Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychol. Sci.* 14, 151–157. doi: 10.1111/1467-9280.01434

Brooks, A., Schouten, B., Troje, N. F., Verfaillie, K., Blanke, O., and van der Zwan, R. (2009). Correlated changes in perceptions of the gender and orientation of ambiguous biological motion figures. *Curr. Biol.* 18, R728–R729. doi: 10.1016/j.cub.2008.06.054

Brown, J., Kaplan, G., Rogers, L. J., and Vallortigara, G. (2010). Perception of biological motion in common marmosets (*Callithrix jacchus*): by females only. *Animal Cogn.* 13, 555–564. doi: 10.1007/s10071-009-0306-0

Burling, J. M., Kadambi, A., Safari, T., and Lu, H. (2019). The impact of autistic traits on self-recognition of body movements. *Front. Psychol.* 9:2687. doi: 10.3389/fpsyg.2018.02687

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: an online study on face covering. *Sci. Rep.* 11:2601. doi: 10.1038/s41598-021-81780-w

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Centelles, L., Assaiante, C., Etchegoyhen, K., Bouvard, M., and Schmitz, C. (2013). From action to interaction: exploring the contribution of body motion cues to social understanding in typical development and in autism spectrum disorders. *J. Autism Dev. Disord.* 43, 1140–1150. doi: 10.1007/s10803-012-1655-0

Clarke, T. J., Bradshaw, M. F., Field, D. T., Hampson, S. E., and Rose, D. (2005). The perception of emotion from body movement in point-light displays of interpersonal dialogue. *Perception* 34, 1171–1180. doi: 10.1068/p5203

Cutting, J. E., Proffitt, D. R., and Kozlowski, L. T. (1978). A biomechanical invariant for gait perception. *J. Exp. Psychol. Hum. Percept. Perform.* 4, 357–372. doi: 10.1037/0096-1523.4.3.357

Dasgupta, S., Tyler, S. C., Wicks, J., Srinivasan, R., and Grossman, E. D. (2017). Network connectivity of the right STS in three social perception localizers. *J. Cogn. Neurosci.* 29, 221–234. doi: 10.1162/jocn_a_01054

Del Valle Rubido, M., McCracken, J. T., Hollander, E., Shic, F., Noeldeke, J., Boak, L., et al. (2018). In search of biomarkers for autism spectrum disorder. *Autism Res.* 11, 1567–1579. doi: 10.1002/aur.2026

Della-Torre, M. E., Zavagno, D., and Actis-Grosso, R. (2021). The interpretation of E-Motions in faces and bodies derived from static artworks by individuals with high functioning autistic spectrum. *Vision (Basel).* 5:17. doi: 10.3390/vision5020017

Dittrich, W. H., Troscianko, T., Lea, S. E., and Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception* 25, 727–738. doi: 10.1068/p250727

Dittrich, W. H. (1991). Das Erkennen von Emotionen aus Ausdrucksbewegungen des Gesichtes [Facial motion and the recognition of emotions]. *Psychol. Beiträge.* 33, 366–377.

Dobs, K., Bülthoff, I., and Schultz, J. (2018). Use and usefulness of dynamic face stimuli for face perception studies - a review of behavioral findings and methodology. *Front. Psychol.* 9:1355. doi: 10.3389/fpsyg.2018.01355

Dodell-Feder, D., Ressler, K. J., and Germine, L. T. (2020). Social cognition or social class and culture? On the interpretation of differences in social cognitive performance. *Psychol. Med.* 50, 133–145. doi: 10.1017/S003329171800404X

Doi, H., Kato, A., Hashimoto, A., and Masataka, N. (2008). Role of biological-motion information in recognition of facial expressions by young children. *Perception* 37, 1399–1411. doi: 10.1068/p5673

Duchesne, A., Pletzer, B., Pavlova, M. A., Lai, M. C., and Einstein, G. (2020). Editorial: Bridging gaps between sex and gender in neurosciences. *Front. Neurosci.* 14:561. doi: 10.3389/fnins.2020.00561

Dziura, S. L., and Thompson, J. C. (2014). Social-network complexity in humans is associated with the neural response to social information. *Psychol. Sci.* 25, 2095–2101. doi: 10.1177/0956797614549209

Engell, A. D., and McCarthy, G. (2013). Probabilistic atlases for face and biological motion perception: an analysis of their reliability and overlap. *Neuroimage* 74, 140–151. doi: 10.1016/j.neuroimage.2013.02.025

Freitag, C. M., Konrad, C., Häberlen, M., Kleser, C., von Gontard, A., Reith, W., et al. (2008). Perception of biological motion in autism spectrum disorders. *Neuropsychologia.* 46, 1480–1494. doi: 10.1016/j.neuropsychologia.2007.12.025

Freitag, C. M., Retz-Junginger, P., Retz, W., Seitz, C., Palmason, H., Meyer J., Rösler, M., et al. (2007). Evaluation der deutschen Version des Autismus-Spektrum-Quotienten (AQ) - die Kurzversion AQ-k [Evaluation of a short German version of the autism spectrum quotient (AQ) – AQ-k]. *Z. Klin. Psychol. Psychother.* 36, 280–289. doi: 10.1026/1616-3443.36.4.280

Gökçen, E., Petrides, K. V., Hudry, K., Frederickson, N., and Smillie, L. D. (2014). Sub-threshold autism traits: the role of trait emotional intelligence and cognitive flexibility. *Br. J. Psychol.* 105, 187–199. doi: 10.1111/bjop.12033

Grosbras, M. H., Beaton, S., and Eickhoff, S. B. (2012). Brain regions involved in human movement perception: A quantitative voxel-based meta-analysis. *Hum. Brain Mapp.* 33, 431–454. doi: 10.1002/hbm.21222

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

He, Z., Liu, Z., Wang, J., and Zhang, D. (2018). Gender differences in processing fearful and angry body expressions. *Front. Behav. Neurosci.* 12:164. doi: 10.3389/fnbeh.2018.00164

Heberlein, A. S., Adolphs, R., Tranel, D., and Damasio, H. (2004). Cortical regions for judgments of emotions and personality traits from point-light walkers. *J. Cogn. Neurosci.* 16, 1143–1158. doi: 10.1162/0898929041920423

Hill, H., Jinno, Y., and Johnston, A. (2003). Comparing solid-body with point-light animations. *Perception* 32, 561–566. doi: 10.1068/p3435

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonséca, D., et al. (2007). Brief report: recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Autism Dev. Disord.* 37, 1386–1392. doi: 10.1007/s10803-006-0275-y

Hull, L., Lai, M. C., Baron-Cohen, S., Allison, C., Smith, P., Petrides, K. V., et al. (2020). Gender differences in self-reported camouflaging in autistic and non-autistic adults. *Autism* 24, 352–363. doi: 10.1177/1362361319864804

Ichikawa, H., Kanazawa, S., Yamaguchi, M. K., and Kakigi, R. (2010). Infant brain activity while viewing facial movement of point-light displays as measured by near-infrared spectroscopy (NIRS). *Neurosci. Lett.* 482, 90–94. doi: 10.1016/j.neulet.2010.06.086

Ichikawa, H., and Yamaguchi, M. K. (2012). Brain activity during face processing in infants. *Brain Nerv.* 64, 761–769.

Isernia, S., Sokolov, A. N., Fallgatter, A. J., and Pavlova, M. A. (2020). Untangling the ties between social cognition and body motion: gender impact. *Front. Psychol.* 11:128. doi: 10.3389/fpsyg.2020.00128

Jack, A., Sullivan, C. A. W., Aylward, E., Bookheimer, S. Y., Dapretto, M., Gaab, N., et al. (2021). A neurogenetic analysis of female autism. *Brain* 144, 1911–1926. doi: 10.1093/brain/awab064

Jastorff, J., Huang, Y. A., Giese, M. A., and Vandenbulcke, M. (2015). Common neural correlates of emotion perception in humans. *Hum. Brain Mapp.* 36, 4184–4201. doi: 10.1002/hbm.22910

Jesse, A., and Bartoli, M. (2018). Learning to recognize unfamiliar talkers: Listeners rapidly form representations of facial dynamic signatures. *Cognition* 176, 195–208. doi: 10.1016/j.cognition.2018.03.018

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Percept. Psychophys.* 14, 201–211. doi: 10.3758/BF03212378

Kaiser, M. D., Hudac, C. M., Shultz, S., Lee, S. M., Cheung, C., Berken, A. M., et al. (2010). Neural signatures of autism. *Proc. Natl. Acad. Sci. U.S.A.* 107, 21223–21228. doi: 10.1073/pnas.1010412107

Kirby, L. A., Moraczewski, D., Warnell, K., Velnoskey, K., and Redcay, E. (2018). Social network size relates to developmental neural sensitivity to biological motion. *Dev. Cogn. Neurosci.* 30, 169–177. doi: 10.1016/j.dcn.2018.02.012

Kirkland, R. A., Peterson, E., Baker, C. A., Miller, S., and Pulos, S. (2013). Meta-analysis reveals adult female superiority in "Reading the Mind in the Eyes" test. *North Am. J. Psychol.* 15, 121–146.

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., and Jones, W. (2009). Two-year-olds with autism orient to nonsocial contingencies rather than biological motion. *Nature* 459, 257–261. doi: 10.1038/nature07868

Koldewyn, K., Whitney, D., and Rivera, S. M. (2010). The psychophysics of visual motion and global form processing in autism. *Brain* 133, 599–610. doi: 10.1093/brain/awp272

Kozlowski, L. T., and Cutting, J. E. (1977). Recognizing the sex of a walker from a dynamic point-light display. *Percept. Psychophys.* 21, 575–580. doi: 10.3758/BF03198740

Kret, M. E., Pichon, S., Grèzes, J., and de Gelder, B. (2011). Men fear other men most: gender specific brain activations in perceiving threat from dynamic faces and bodies - an FMRI study. *Front. Psychol.* 2:3. doi: 10.3389/fpsyg.2011.00003

Krüger, S., Sokolov, A. N., Enck, P., Krägeloh-Mann, I., and Pavlova, M. A. (2013). Emotion through locomotion: gender impact. *PLoS One.* 8:e81716. doi: 10.1371/journal.pone.0081716

Kynast, J., Polyakova, M., Quinque, E. M., Hinz, A., Villringer, A., and Schroeter, M. L. (2021). Age- and sex-specific standard scores for the Reading the Mind in the Eyes Test. *Front. Aging. Neurosci.* 12:607107. doi: 10.3389/fnagi.2020.607107

Lawrence, K. E., Hernandez, L. M., Eilbott, J., Jack, A., Aylward, E., Gaab, N., et al. (2020). Neural responsivity to social rewards in autistic female youth. *Transl. Psychiatry* 10:178. doi: 10.1038/s41398-020-0824-8

Lorey, B., Kaletsch, M., Pilgramm, S., Bischoff, M., Kindermann, S., Sauerbier, I., et al. (2012). Confidence in emotion perception in point-light displays varies with the ability to perceive own emotions. *PLoS One* 7:e42169. doi: 10.1371/journal.pone.0042169

Ma, Y., Paterson, H. M., and Pollick, F. E. (2006). A motion capture library for the study of identity, gender, and emotion perception from biological motion. *Behav. Res. Methods.* 38, 134–141. doi: 10.3758/bf03192758

Maenner, M. J., Shaw, K. A., Baio, J., Washington, A., Patrick, M., DiRienzo, M., et al. (2020). Prevalence of autism spectrum disorder among children aged 8 years - Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2016. *MMWR Surveill. Summ.* 69, 1–12. doi: 10.15585/mmwr.ss6904a1

Manera, V., Schouten, B., Becchio, C., Bara, B. G., and Verfaillie, K. (2010). Inferring intentions from biological motion: a stimulus set of point-light communicative interactions. *Behav. Res. Methods.* 42, 168–178. doi: 10.3758/BRM.42.1.168

Marmolejo-Ramos, F., Murata, A., Sasaki, K., Yamada, Y., Ikeda, A., Hinojosa, J. A., et al. (2020). Your face and moves seem happier when I smile. *Exp. Psychol.* 67, 14–22. doi: 10.1027/1618-3169/a000470

Mazzoni, N., Jacobs, C., Venuti, P., Silvanto, J., and Cattaneo, L. (2017). State-dependent TMS reveals representation of affective body movements in the anterior intraparietal cortex. *J. Neurosci.* 37, 7231–7239. doi: 10.1523/JNEUROSCI.0913-17.2017

Mazzoni, N., Landi, I., Ricciardelli, P., Actis-Grosso, R., and Venuti, P. (2020). Motion or emotion? Recognition of emotional bodily expressions in children with autism spectrum disorder with and without intellectual disability. *Front. Psychol.* 11:478. doi: 10.3389/fpsyg.2020.00478

Mazzoni, N., Ricciardelli, P., Actis-Grosso, R., and Venuti, P. (2021). Difficulties in recognising dynamic but not static emotional body movements in autism spectrum disorder. *J. Autism Dev. Disord.* 52, 1092–1105. doi: 10.1007/s10803-021-05015-7

Megías-Robles, A., Gutiérrez-Cobo, M. J., Cabello, R., Gómez-Leal, R., Baron-Cohen, S., and Fernández-Berrocal, P. (2020). The 'Reading the Mind in the Eyes' test and emotional intelligence. *R. Soc. Open Sci.* 7:201305. doi: 10.1098/rsos.201305

Miller, L. E., and Saygin, A. P. (2013). Individual differences in the perception of biological motion: links to social cognition and motor imagery. *Cognition* 128, 140–148. doi: 10.1016/j.cognition.2013.03.013

Murphy, P., Brady, N., Fitzgerald, M., and Troje, N. F. (2009). No evidence for impaired perception of biological motion in adults with autistic spectrum disorders. *Neuropsychologia* 47, 3225–3235. doi: 10.1016/j.neuropsychologia.2009.07.026

Nackaerts, E., Wagemans, J., Helsen, W., Swinnen, S. P., Wenderoth, N., and Alaerts, K. (2012). Recognizing biological motion and emotions from point-light displays in autism spectrum disorders. *PLoS One* 7:e44473. doi: 10.1371/journal.pone.0044473

Pavlova, M., Guerreschi, M., Lutzenberger, W., Sokolov, A. N., and Krägeloh-Mann, I. (2010). Cortical response to social interaction is affected by gender. *Neuroimage* 50, 1327–1332. doi: 10.1016/j.neuroimage.2009.12.096

Pavlova, M. A., Erb, M., Hagberg, G. E., Loureiro, J., Sokolov, A. N., and Scheffler, K. (2017). 'Wrong way up': Temporal and spatial dynamics of the networks for body motion processing at 9.4 T. *Cereb. Cortex.* 27, 5318–5330. doi: 10.1093/cercor/bhx151

Pavlova, M. A., Galli, J., Zanetti, F., Pagani, F., Micheletti, S., Rossi, A., et al. (2021). Social cognition in individuals born preterm. *Sci. Rep.* 11:14448. doi: 10.1038/s41598-021-93709-4

Pavlova, M. A., and Krägeloh-Mann, I. (2013). Limitations on the developing preterm brain: impact of periventricular white matter lesions on brain connectivity and cognition. *Brain* 136(Pt 4), 998–1011. doi: 10.1093/brain/aws334

Pavlova, M. A., Mayer, A., Hösl, F., and Sokolov, A. N. (2016). Faces on her and his mind: female and likable. *PLoS One* 11:e0157636. doi: 10.1371/journal.pone.0157636

Pavlova, M. A., Romagnano, V., Fallgatter, A. J., and Sokolov, A. N. (2020). Face pareidolia in the brain: Impact of gender and orientation. *PLoS One.* 15:e0244516. doi: 10.1371/journal.pone.0244516

Pavlova, M. A., and Sokolov, A. A. (2022a). Reading covered faces. *Cereb. Cortex.* 32, 249–265.

Pavlova, M. A., and Sokolov, A. A. (2022b). Reading language of the eyes. *Neurosci. Biobehav. Rev.* 140:104755. doi: 10.1016/j.neubiorev.2022.104755

Pavlova, M. A., Sokolov, A. N., and Bidet-Ildei, C. (2015). Sex differences in the neuromagnetic response to biological motion. *Cereb. Cortex* 25, 3468–3474. doi: 10.1093/cercor/bhu175

Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. *Cereb. Cortex* 22, 981–995. doi: 10.1093/cercor/bhr156

Pavlova, M. A. (2017a). Emotion science in the twenty-first century. Time, sex, and behavior in emotion science: over and above. *Front. Psychol.* 8:1211. doi: 10.3389/fpsyg.2017.01211

Pavlova, M. A. (2017b). Sex and gender affect the social brain: Beyond simplicity. *J. Neurosci. Res.* 95, 235–250. doi: 10.1002/jnr.23871

Peñuelas-Calvo, I., Sareen, A., Sevilla-Llewellyn-Jones, J., and Fernández-Berrocal, P. (2019). The "Reading the Mind in the Eyes" test in autism-spectrum disorders comparison with healthy controls: a systematic review and meta-analysis. *J. Autism Dev. Disord.* 49, 1048–1061. doi: 10.1007/s10803-018-3814-4

Pollick, F. E., Hill, H., Calder, A., and Paterson, H. (2003). Recognising facial expression from spatially and temporally modified movements. *Perception* 32, 813–826. doi: 10.1068/p3319

Pollick, F. E., Kay, J. W., Heim, K., and Stringer, R. (2005). Gender recognition from point-light walkers. *J. Exp. Psychol. Hum. Percept. Perform.* 31, 1247–1265. doi: 10.1037/0096-1523.31.6.1247

Pollick, F. E., Paterson, H. M., Bruderlin, A., and Sanford, A. J. (2001). Perceiving affect from arm movement. *Cognition* 82, B51–B61. doi: 10.1016/s0010-0277(01)00147-0

Proverbio, A. M., and Cerri, A. (2022). The recognition of facial expressions under surgical masks: The primacy of anger. *Front. Neurosci.* 16:864490. doi: 10.3389/fnins.2022.864490

Quinto, L. R., Thompson, W. F., Kroos, C., and Palmer, C. (2014). Singing emotionally: a study of pre-production, production, and post-production facial expressions. *Front. Psychol.* 5:262. doi: 10.3389/fpsyg.2014.00262

Reid, V. M., Hoehl, S., and Striano, T. (2006). The perception of biological motion by infants: an event-related potential study. *Neurosci. Lett.* 395, 211–214. doi: 10.1016/j.neulet.2005.10.080

Rice, K., Anderson, L. C., Velnoskey, K., Thompson, J. C., and Redcay, E. (2016). Biological motion perception links diverse facets of theory of mind during middle childhood. *J. Exp. Child. Psychol.* 146, 238–246. doi: 10.1016/j.jecp.2015.09.003

Ross, P., and George, E. (2022). Are face masks a problem for emotion recognition? Not when the whole body is visible. *Front. Neurosci.* 16:915927. doi: 10.3389/fnins.2022.915927

Rosenblum, L. D., Johnson, J. A., and Saldaña, H. M. (1996). Point-light facial displays enhance comprehension of speech in noise. *J. Speech Hear. Res.* 39, 1159–1170. doi: 10.1044/jshr.3906.1159

Rugani, R., Rosa Salva, O., Regolin, L., and Vallortigara, G. (2015). Brain asymmetry modulates perception of biological motion in newborn chicks (*Gallus gallus*). *Behav. Brain Res.* 290, 1–7. doi: 10.1016/j.bbr.2015.04.032

Rutherford, M. D., and Troje, N. F. (2012). IQ predicts biological motion perception in autism spectrum disorders. *J. Autism Dev. Disord.* 42, 557–565. doi: 10.1007/s10803-011-1267-0

Schiffer, B., Pawliczek, C., Müller, B. W., Gizewski, E. R., and Walter, H. (2013). Why don't men understand women? Altered neural networks for reading the language of male and female eyes. *PLoS One* 8:e60278. doi: 10.1371/journal.pone.0060278

Schouten, B., Troje, N. F., Brooks, A., van der Zwan, R., and Verfaillie, K. (2010). The facing bias in biological motion perception: Effects of stimulus gender and observer sex. *Atten. Percept. Psychophys.* 72, 1256–1260. doi: 10.3758/APP.72.5.1256

Schouten, B., Troje, N. F., and Verfaillie, K. (2011). The facing bias in biological motion perception: Structure, kinematics, and body parts. *Atten. Percept. Psychophys.* 73, 130–143. doi: 10.3758/s13414-010-0018-1

Sevdalis, V., and Keller, P. E. (2011). Perceiving performer identity and intended expression intensity in point-light displays of dance. *Psychol Res.* 75, 423–434. doi: 10.1007/s00426-010-0312-5

Sevdalis, V., and Keller, P. E. (2012). Perceiving bodies in motion: expression intensity, empathy, and experience. *Exp. Brain Res.* 222, 447–453. doi: 10.1007/s00221-012-3229-y

Simmons, D., Dorsi, J., Dias, J. W., and Rosenblum, L. D. (2021). Cross-modal transfer of talker-identity learning. *Atten. Percept. Psychophys.* 83, 415–434. doi: 10.3758/s13414-020-02141-9

Soken, N. H., and Pick, A. D. (1992). Intermodal perception of happy and angry expressive behaviors by seven-month-old infants. *Child. Dev.* 63, 787–795. doi: 10.1111/j.1467-8624.1992.tb01661.x

Sokolov, A. A., Krüger, S., Enck, P., Krägeloh-Mann, I., and Pavlova, M. A. (2011). Gender affects body language reading. *Front. Psychol.* 2:16. doi: 10.3389/fpsyg.2011.00016

Sokolov, A. A., Zeidman, P., Erb, M., Pollick, F. E., Fallgatter, A. J., Ryvlin, P., et al. (2020). Brain circuits signaling the absence of emotion in body language. *Proc. Natl. Acad. Sci. U.S.A.* 117, 20868–20873. doi: 10.1073/pnas.2007141117

Sokolov, A. A., Zeidman, P., Erb, M., Pollick, F. E., Ryvlin, P., Friston, K. J., et al. (2018). Structural and effective brain connectivity underlying biological motion detection. *Proc. Natl. Acad. Sci. U.S.A.* 115, E12034–E12042. doi: 10.1073/pnas.1812859115

Sotoodeh, M. S., Taheri-Torbati, H., Hadjikhani, N., and Lassalle, A. (2021). Preserved action recognition in children with autism spectrum disorders: Evidence from an EEG and eye-tracking study. *Psychophysiology* 58:e13740. doi: 10.1111/psyp.13740

Spencer, J. M., Sekuler, A. B., Bennett, P. J., Giese, M. A., and Pilz, K. S. (2016). Effects of aging on identifying emotions conveyed by point-light walkers. *Psychol. Aging* 31, 126–138. doi: 10.1037/a0040009

Swain, R. H., O'Hare, A. J., Brandley, K., and Gardner, A. T. (2022). Individual differences in social intelligence and perception of emotion expression of masked and unmasked faces. *Cogn. Res. Princ. Implic.* 7:54. doi: 10.1186/s41235-022-00408-3

Thoresen, J. C., Vuong, Q. C., and Atkinson, A. P. (2012). First impressions: gait cues drive reliable trait judgements. *Cognition* 124, 261–271. doi: 10.1016/j.cognition.2012.05.018

Tomlinson, E. K., Jones, C. A., Johnston, R. A., Meaden, A., and Wink, B. (2006). Facial emotion recognition from moving and static point-light images in schizophrenia. *Schizophr. Res.* 85, 96–105. doi: 10.1016/j.schres.2006.03.018

Vaskinn, A., Sundet, K., Østefjells, T., Nymo, K., Melle, I., and Ueland, T. (2016). Reading emotions from body movement: a generalized impairment in schizophrenia. *Front. Psychol.* 6:2058. doi: 10.3389/fpsyg.2015.02058

Wang, Y., Wang, L., Xu, Q., Liu, D., Chen, L., Troje, N. F., et al. (2018). Heritable aspects of biological motion perception and its covariation with autistic traits. *Proc. Natl. Acad. Sci. U.S.A.* 115, 1937–1942. doi: 10.1073/pnas.1714655115

White, S., Hill, E., Happé, F., and Frith, U. (2009). Revisiting the strange stories: revealing mentalizing impairments in autism. *Child. Dev.* 80, 1097–1117. doi: 10.1111/j.1467-8624.2009.01319.x

Williamson, K. E., Jakobson, L. S., Saunders, D. R., and Troje, N. F. (2015). Local and global aspects of biological motion perception in children born at very low birth weight. *Child. Neuropsychol.* 21, 603–628. doi: 10.1080/09297049.2014.945407

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Perceptions of persons who wear face coverings are modulated by the perceivers' attitude

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We examined if the effect of facial coverings on person perception is influenced by the perceiver's attitudes. We used two online experiments in which participants saw the same human target persons repeatedly appearing with and without a specific piece of clothing and had to judge the target persons' character. In Experiment 1 (N = 101), we investigated how the wearing of a facial mask influences a person's perception depending on the perceiver's attitude toward measures against the COVID-19 pandemic. In Experiment 2 (N = 114), we examined the effect of wearing a head cover associated with Arabic culture on a person's perception depending on the perceiver's attitude toward Islam. Both studies were preregistered; both found evidence that a person's perception is a process shaped by the personal attitudes of the perceiver as well as merely the target person's outward appearance. Integrating previous findings, we demonstrate that facial covers, as well as head covers, operate as cues which are used by the perceivers to infer the target persons' underlying attitudes. The judgment of the target person is shaped by the perceived attitude toward what the facial covering stereotypically symbolizes.

KEYWORDS
head cover, facial mask, COVID-19, attractiveness, prosociality, social attitude, theory of mind, hijab

Introduction

Perceived attractiveness, liking, and character judgments of people wearing facial covering are strongly influenced by the attitude of the perceiver.

Humans infer on characteristics of others based on visible cues. The judgments of attractiveness (Carbon et al., 2010), liking, and personal character are based on visual cues, particularly in faces (Willis and Todorov, 2006; Todorov et al., 2014). While cues seem to be universal for attractiveness as rater agreement measured is high between different perceivers (Langlois et al., 2000), the judgment of attractiveness is fueled by personal taste and shared taste, suggesting that cues are interpreted to equal parts based on commonly held assumptions and uniquely held assumptions (Hönekopp, 2006). The similarity of facial features with personally relevant others fuels the personal component of judgment (Kraus and Chen, 2010; Günaydin et al., 2012). Stereotypes are shared social knowledge regarding specific groups, which result in person judgments (Maddox, 2004) and can even influence behavior such as trusting (Stanley et al., 2011) or concrete social behavior such as helpfulness (see Wheeler and Petty, 2001).

Humans do not rely on faces alone when judging their counterparts but also use other cues. These cues can stem from a wide range of visible properties, for example, a person's clothing to infer their self-concept (Piacentini and Mailer, 2004), a person's hair to infer their ideology (Synnott, 1987), or religious paraphernalia to assess a person's religion and cultural heritage (Taylor et al., 2010; Desai and Kouchaki, 2017).

These findings point to the effect of top-down information processing during person perception. Cues activate certain schemata that are associated with specific characterizations, which in turn are applied to the specific person. This fast initial assessment carries over onto subsequent appraisals and behavior toward the object of assessment as the first impression is stable over time (Willis and Todorov, 2006).

The outside appearances of people matter, because the top-down judgments guided by these visible cues have far-reaching consequences. Meta-analyses show consistently that the skin color of the judged person influences the jury's decisions concerning convictions (Mitchell et al., 2005) and workplace decisions (Koch et al., 2015), and a similar effect is observed for attractiveness (Mazzella and Feingold, 1994). Importantly, in the case of juror decisions, these effects seem to be moderated by characteristics on the perceiver side (Devine and Caughlin, 2014). But do perceiver characteristics in general shape the perception of others depending on the visual cues they have? Further factors seem to matter, most importantly, visual perception of social categories is also known to be shaped by higher order social cognitive processes. If we show negative attitudes, possess stereotypes about certain groups of persons or if we follow specific goals, our visual perception is biased (Freeman and Johnson, 2016), which can lead to very unfortunate, e.g., racial biases (Harsányi and Carbon, 2015; Bagnis et al., 2020). Understanding such mechanisms involved in making initial (and sometimes persistent) judgments is crucial in understanding human interactions.

Previous research has shown that top-down information processing is induced by cues, which then shape a person's perception (Carbon et al., 2018). Wearing a mask by a target person is a specific cue for underlying attitudes, importantly, person perception is not only a function of the attitudes of the target person but also of the perceivers' attitudes—we like people who are similar to us (Byrne and Griffitt, 1973). Attraction to strangers and perceived similarity correlate with $r = 0.49$ according to a meta-analysis (Montoya et al., 2008). Importantly, the studies investigating the effect of attitude similiarity between the perceived and the perceiver on person judgments explicitly present the attitude of the stranger to participants (e.g., Pilkington and Lydon, 1997; Singh et al., 2007). Facial coverings in many ways are a signal of specific attitudes held by the wearer. A person wearing a Kippah is potentially expressing Jewish faith, and persons wearing MAGA caps aim to express their support for Donald Trump. Are these facial coverings affecting how the person wearing them is perceived, depending on the perceiver's attitudes?

In the present study, two cues are examined, which are imperative to be understood particularly in today's political and social climates: medical face-coverings and Arabic headdresses. We aim to show that cues are not judged equally but their implications for characterization are dependent on the perceiver.

The present research

To what degree does the judgment of another person depend on the perceiver's attitude toward an issue associated with the visible cue, that is, its' symbolic value, but not the person itself? Investigating the effect of cues and attitudes held by the perceiver and their combined effect on person judgments—racial prejudice has been a prominent example. However, studies focused on racial prejudice and its effect on person perception (e.g., Blair, 2002; Maddox and Gray, 2002; Hugenberg and Sacco, 2008; Quinn and Macrae, 2011) cannot disentangle the effect of the target person and the target person's appearance linked to the symbol (skin color). Studies interested in the effects of symbols added to the person, such as status symbols, show that the effect of these symbols differs depending on the perceiver (friends vs. strangers) (Garcia et al., 2019). However, here the influence of personal attitudes of the perceiver was not examined—but considering research on stereotypes, the attitude toward the group or issue, the symbol stands for, should explain the shift in judgment. The values of certain symbols are in the eye of the beholder: wearing a mask against COVID-19 could be such a symbol and wearing a *hijab* in females or a *kufiya* in males could be another. We were interested in the effect of these two facial coverings and the perceiver's attitudes toward issues associated with these facial coverings on person perception and character judgments.

Experiment 1

Does the attitude toward measures against COVID-19 influence the perception of a target person wearing masks or no masks regarding the target person's attractiveness, liking, and character? Previous research shows that wearing a mask results in more positive judgments for some samples (Oldmeadow and Koch, 2021; Hies and Lewis, 2022) but more negative

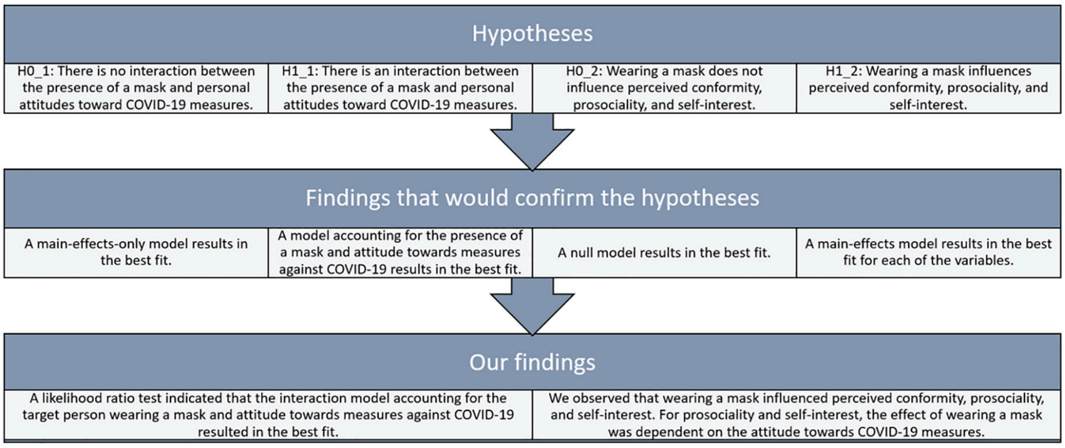

FIGURE 1
Hypotheses, predicted observations, and findings for experiment 1.

judgments for others (Miyazaki and Kawahara, 2016). Based on our theorizing, we assume that this difference is explained by the underlying differences in attitudes of the perceivers. In an online experiment, we asked participants to repeatedly rate a target person shown in a public place regarding the target person's character. We varied whether the person wore a facial mask or not to test our two main hypotheses: First, with an increasingly positive attitude toward measures against COVID-19, a person wearing a mask is evaluated more positively on the dimensions of attractiveness and liking than without a mask. Conversely, a target person without a mask is evaluated more positively with decreasing positive attitude toward measures against COVID-19. Second, a target person's conformity is judged higher with an increasingly critical view of measures against COVID-19, a target person's prosociality is judged lower with increasing critical view of measures against COVID-19, and a target person's self-interest is judged lower with increasing critical view of measures against COVID-19. For Experiment 1, hypotheses and findings are summarised in **Figure 1**.

Materials and methods

Sample and design

All materials and the preregistration, registered before data collection, are available at https://osf.io/xqmpw?view_only=64cbd820d23f4bc7b3d84b396ae6c8e4.

The relevant hypothesis for the power analysis, which determined the sample size, was Hypothesis 1 (H1). H1 is an interaction of mask (yes vs. no) and personal attitude toward COVID-19 measures (continuous). We tested two interaction effects, one for liking and one for attractiveness. We used R package {simR} (Green and Macleod, 2016) for the power calculation on basis of a random-effects model accounting for the employed repeated measures design. Detailed model assumptions are explained in the preregistration file. The effect in question is the fixed effect of the interaction between the attitude toward measures against COVID-19 with wearing a mask or not and was set to β = 0.15, given that r and β are equivalent when predictors are independent [(Peterson and Brown, 2005) this represents a small effect]. To observe that this effect explains a significant amount of variance compared to the main effects only model with α = 0.01 and a satisfactory test power $1 - \beta$ of 0.80 we collected data from N = 101 participants (M_{age} = 35.9 years, 75 women, 23 men, and 1 participant assigned to the "other" category; see **Supplementary Table 1** in **Electronic supplement A**).

Participants' attitude toward measures against COVID-19 was assessed. Participants were then asked to rate two people depicted under varying conditions, which resulted in an orthogonal within-participants design of the varying factors mask (yes vs. no), target person (male vs. female), and partner (both appear the same way vs. target person differs from other).

Material

Attitude toward measures against COVID-19

The participants' attitude toward measures against COVID-19 was measured with a self-constructed scale consisting of seven items and their order was randomized before the study. All items are listed in **Table 1**. Participants responded to each item on a five-point scale (1 = *strong disagreement [starke Ablehnung]*, 2 = *disagreement [Ablehnung]*, 3 = *neutral [neutral]*, 4 = *agreement [Zustimmung]*, 5 = *strong agreement [starke Zustimmung]*—original German terms in brackets).

The scale reflected each participant's mean score and showed satisfactory consistency expressed by a Cronbach's α = 0.77, M = 3.4, and SD = 0.77.

FIGURE 2
Stimuli used in experiment 1. The figure shows all variations for the male target person. For the female target person, the arrow was moved above the female, respectively. To ensure the anonymity of the people displayed in the photograph, faces were blurred for the published manuscript. The original photo (without face masks and blurring effects) was kindly made public by Jason Pier through a CC BY-NC 2.0 license.

TABLE 1 Items for attitude toward measures against COVID-19 (original German terms in brackets).

No.	Item
(1)	(−) The protective measures are very stressful for me. [Die Schutzmaßnahmen sind für mich sehr belastend.]
(2)	(−) I feel that my freedom is severely restricted by the government's measures. [Ich fühle mich in meinen Freiheiten stark eingeschränkt durch die Maßnahmen der Regierung.]
(3)	(−) I think government measures, such as Contact restrictions are excessive. [Ich denke, die Maßnahmen der Regierung, wie z.B. Kontaktbeschränkungen, sind überzogen.]
(4)	(−) I feel economically very threatened by the measures against COVID-19 [Ich fühle mich wirtschaftlich sehr bedroht durch Maßnahmen gegen COVID-19.]
(5)	(−) I think COVID-19 is no worse than influenza. [Ich denke COVID-19 ist nicht schlimmer als eine Influenza.]
(6)	I find protective masks a very good way to protect yourself and others from COVID-19. [Ich finde Schutzmasken eine sehr gute Möglichkeit sich und andere vor COVID-19 zu schützen.]
(7)	I feel very threatened by COVID-19. [Ich fühle mich gesundheitlich sehr bedroht durch COVID-19.]

(−) indicate reversed items.

Stimuli

The photograph used as a base stimulus showed a family consisting of two adults and two children. The picture was edited in three ways to avoid confounding. First, the background was blurred so that only the family was in focus and no specifics about the general wearing of masks of other persons were provided—still the picture made the impression that the small family was in the middle of a frequented market square. Second, the respective mask was added or taken away in the same picture. Third, a yellow arrow was added above the target person to indicate who was to be judged by the participant (see Figure 2).

Dependent variables

The study was carried out in German, but the items in Table 2 are presented in English here. All items were measured on a 7-point rating scale (1 = *fully disagree [trifft gar nicht zu]*, 7 = *fully agree [trifft vollkommen zu]*).

The measure of three characteristics of the target persons, perceived conformity, perceived prosociality, and perceived self-interest consisted of three items each. Items #1–#9 were aggregated to three scales reflecting *Conformity* (Items #1–#3), *Prosociality* (Items #4–#6), and *Self-interest* (Items #7–#9). We conducted a multilevel reliability analysis with the package {psych} (Revelle, 2019). The reliability for each scale, conformity, prosociality, and self-interest, was estimated based on Formula #11 given by Shrout and Lane (2013). This formula estimates the reliability of between-person differences, averaged over items. The resulting coefficient is referred to as *Rcn*. The respective *Rcn* for conformity was 0.62, for prosociality was 0.70, and for self-interest was 0.61.

Procedure

Between 29 May 2020 and 25 June 2020, participants were invited to an online study through different recruitment tools, mainly a university-specific one and a mailing list using ORSEE (Greiner, 2015). Furthermore, participants' attitudes toward measures against COVID-19 were assessed. Then, participants viewed eight consecutive pictures showing a small family (consisting of a mother, a father, a female child at kindergarten

TABLE 2 Items measuring how the participant perceives the target person (the original wording in German is given in brackets).

No	Item
(1)	The person wants to avoid being noticed negatively [Die Person will vermeiden negativ aufzufallen]
(2)	The person wants to be socially accepted [Die Person will sozial akzeptiert sein]
(3)	The person simply follows the government's recent recommendations [Die Person folgt einfach den jüngsten Empfehlungen der Regierung]
(4)	The person wants to protect others [Die Person will andere schützen]
(5)	The person thinks s/he may be ill and wants to protect other people from infection [Die Person denkt, sie könnte erkrankt sein und will andere Menschen vor einer Ansteckung schützen]
(6)	The person is very prosocial [Die Person ist sehr prosozial]
(7)	The person thinks primarily of herself/himself and does not want to be infected by others, although the probability of this is very low [Die Person denkt primär an sich selbst und will nicht infiziert werden von anderen, obwohl die Wahrscheinlichkeit davon sehr gering ist]
(8)	The person wants to protect himself [Die Person will sich schützen]
(9)	The person is afraid [Die Person hat Angst]
(10)	The person has the coronavirus [Die Person hat das Coronavirus]
(11)	The person is much more scared than s/he should be [Die Person hat viel mehr Angst als sie haben sollte]
(12)	The person looks strange [Die Person sieht eigenartig aus]
(13)	The person is careful [Die Person ist umsichtig]
(14)	The person is neurotic [Die Person ist neurotisch]
(15)	The person is aggressive [Die Person ist aggressiv]
(16)	The person is attractive [Die Person ist attraktiv]
(17)	The person is liked by me [Die Person ist sympathisch]

Here the English translation is shown. Original German wording in brackets. The two main dependent variables were attractiveness and liking—they were both measured by one single item each. Perceived attractiveness was measured with Item #16, and liking was assessed with Item #17.

age, and a male child at toddler age sitting in a baby buggy) standing in a public place. The order of pictures was randomized for each participant. Participants were asked to rate the target person in the picture (the target person was indicated by a vertical arrow from above, directed toward the person's head; for an illustration of typical stimuli, see **Figure 2**). The ratings captured liking, attractiveness, perceived prosociality, perceived conformity, and perceived self-interest of the target person. The setting of the pictures was identical, with the exception that we systematically manipulated whether the adults wore a mask or not with all combinations being available (female/male: no mask/no mask, no mask/mask, mask/no mask, and mask/mask), we further manipulated which adult we indicated as target person (mother vs. father). After completion of the eight trials, one picture was randomly selected and presented to a participant, who was asked to provide a written description of the scene including what they thought was on the mind of the depicted people. This measure was not relevant to the current study. Finally, participants responded to the questions about demographics and were thanked for their participation.

Statistical analysis

We used linear multilevel regressions with participants' ID as a random effect to account for the repeated measures. For the analysis, we mean-centered the variable attitude toward measures against COVID-19; all factorial variables were dummy coded. For executing the multilevel linear analyses, we used the R package {lmer} (Bates et al., 2015). For the analysis of slopes, we used the R package {interactions} (Long, 2019). Because treating ordinal responses as continuous can result in wrong inferences (Liddell and Kruschke, 2018), we also report results based on an ordinal regression in a Bayesian fashion (see **Electronic supplement F**).

Results

Test of preregistered hypothesis H1

We observed that perceived attractiveness and liking were dependent on the participants' attitude toward measures against COVID-19 and whether the target person was wearing a mask or not (see **Figure 3**). We fit regression models for attractiveness and liking individually (for all estimates, see **Supplementary Table 2** in the **Electronic supplement**).

A likelihood ratio test indicated that the interaction model accounting for the target person wearing a mask and attitude toward measures against COVID-19 resulted in the best fit compared to the main effects only model, χ^2 (1) = 23.17, $p < 0.001$—fixed effects explained 3% of the variance (marg. $R^2 = 0.03$). Adding the other interactions did not significantly improve the overall fit. The effect of wearing a mask compared to not wearing a mask on attractiveness, $\beta = 0.00$, 95% CI [−0.05, 0.04], was moderated by the attitude toward measures against COVID-19, $\beta = 0.12$, 95% CI [0.07, 0.17]. To test in which regions the slopes differed, we used the Johnson-Neyman procedure which estimates the region of a significant difference between the slopes. The region of a significant difference of slopes depending on the moderator was [−0.46, +1.65] and participants' who had attitudes outside below/ above these boundaries had lower/higher judgment about the attractiveness of a target person with a mask compared to the same target person without a mask.

For liking, we observed the same pattern of results. The interaction model including the interaction of mask and

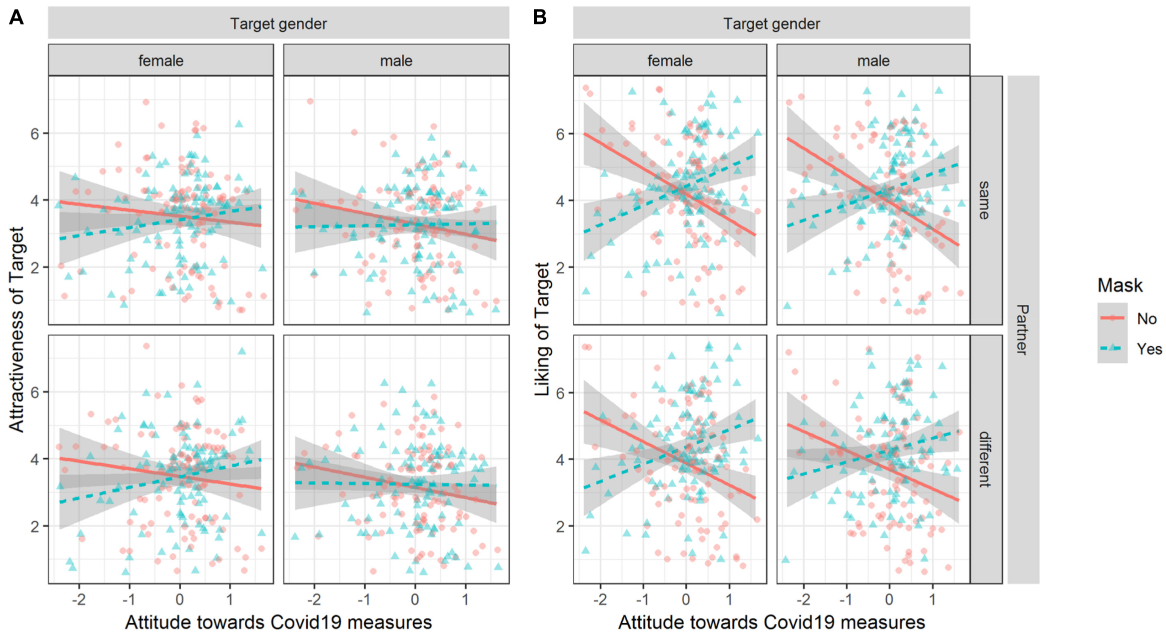

FIGURE 3
Observed attractiveness and liking ratings dependent on attitude, mask, target person gender, and partner. Plot **(A)** for attractiveness. Plot **(B)** for liking. Lines depict linear regression of Y on X and the shaded area shows the 95% CI of the estimate. Data points are jittered to avoid overlap.

attitudes toward measures against COVID-19 resulted in a better fit compared to the main effects only model, χ^2 (1) = 127.33, $p < 0.001$; fixed effects explained 13% of the variance (marg. $R^2 = 0.13$). Adding the other interactions did not significantly increase fit. The effect of wearing a mask compared to not wearing a mask on liking, β = 0.14, 95% CI [0.09, 0.20], was moderated by the attitude toward measures against COVID-19, β = 0.31, 95% CI [0.26, 0.36].

The region of significant difference of slopes depending on the moderator was [−0.45, 0.04] and participants who have attitudes below/above these boundaries expressed less/more liking when comparing a person with a mask to the same person without a mask. We obtained the same significant interaction effects supporting H1 when using a Bayesian ordered-probit regression (see **Electronic supplement C**).

Test of preregistered hypothesis H2

We observed that wearing a mask influenced perceived conformity, prosociality, and self-interest. For prosociality and self-interest, the effect of wearing a mask was dependent on the attitude toward COVID-19 measures (see **Figure 4**).

We fit three linear regression models for conformity, prosociality, and self-interest. Conformity was dependent on wearing a mask or not (for all estimates, see **Supplementary Table 3** in the **Electronic supplement**). For conformity, the main effects model fit the data best, compared to the null model, χ^2 (4) = 427.64, $p < 0.001$; fixed effects explained 40% of the variance (marg. $R^2 = 0.40$). Adding the other interactions did not significantly increase fit. In the full factorial model, conformity was judged higher for target persons wearing a mask compared to target persons not wearing a mask, β = 0.62, 95% CI [0.58, 0.67].

For prosociality, the interaction model, including the interaction of mask and attitudes toward measures against COVID-19, resulted in a better fit compared to the main effects only model, χ^2 (1) = 127.33, $p < 0.001$, and fixed effects explained 60% of the variance (marg. $R^2 = 0.60$). Prosociality was judged higher when the target person was wearing a mask compared to not wearing a mask, β = 0.75, 95% CI [0.71, 0.79]. This effect was moderated by the attitude toward measures against COVID-19, β = 0.22, 95% CI [0.18, 0.26]. The region of significant difference of slopes depending on the moderator was [−2.86, −1.54]. Participants who had attitudes below/above these boundaries judged prosociality more negatively/positively when comparing a person with a mask to the same person without a mask.

For self-interest, the interaction model including the interaction of mask and attitudes toward measures against COVID-19 resulted in a better fit compared to the main effects only model, χ^2 (1) = 6.67, $p = 0.01$, and fixed effects explained 47% of the variance (marg. $R^2 = 0.47$). Self-interest was judged higher when the target person was wearing a mask compared to not wearing a mask, β = 0.67, 95% CI [0.63, 0.72]. This effect was

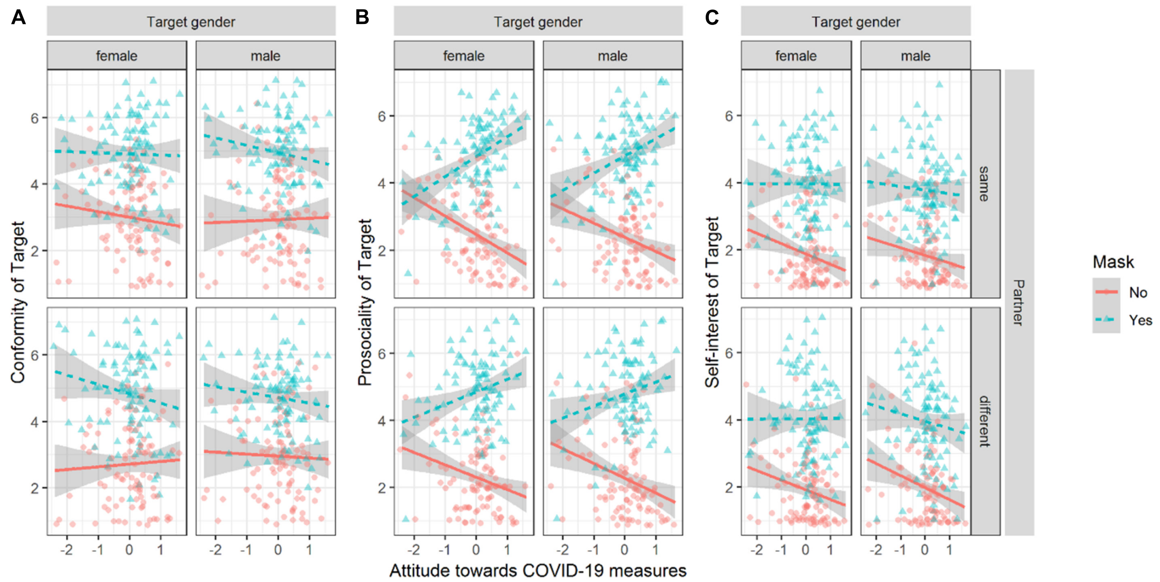

FIGURE 4
Perceived judgment of the target person depending on mask, partner, and gender of target person. Plot **(A)** for perceived conformity, plot **(B)** for perceived prosociality, and Plot **(C)** for self-interest. Lines depict linear regression of Y on X; the shaded area indicates the 95% CI of the estimate. Points are jittered to avoid overlap.

moderated by the attitude toward measures against COVID-19, $\beta = 0.06$, 95% CI [0.01, 0.10]. The region of significant difference of slopes depending on the moderator is inside the interval of [−3.24, 99.41], and none of the observed values fall outside this area (they are restricted to [−3, 3]). The slope of the effect of wearing a mask or not is positive for all observed attitudes toward measures against COVID-19.

Robustness check

To check the robustness of our results, we used a Bayesian analysis for ordinal linear regression. The results are consistent with our main analysis. Estimates and plots of marginal effects are found in Electronic supplement C.

Discussion

We observed that the perception of a person wearing a mask or not (the target person) is dependent on the perceiver. The main hypothesis (H1) was an interaction of mask (yes vs. no) and personal attitude toward COVID-19 measures (continuous) for perceived attractiveness as well as for liking of the target person. Our data corroborated H1. Target persons wearing masks are perceived as more attractive and are more liked by people who have strong positive attitudes toward measures against COVID-19, but people who have strong negative attitudes toward measures against COVID-19 do not perceive them as more attractive and do not like them more. For target persons not wearing a mask, the direction of the relationship between attitude and judgment of the target person was reversed. The effects were stronger for liking than for attractiveness. In line with H2, we observed that perceived prosociality and self-interest were the results of an interaction between the target person wearing a mask or not and the perceivers' attitude toward COVID-19. We did not observe this interaction in the case of conformity judgments.

Wearing masks is a new phenomenon in Western countries and wearing masks or not has direct social consequences—but does the effect observed with masks generalize to the perception of people wearing other symbols which indicate attitudes such as religion? To answer this question, we carried out Experiment 2.

Experiment 2

The second study investigated if the effect of mask-wearing is dependent on the attitudes of the perceiver and is a general property of person perception. For this reason, in Experiment 2, we inspected the effect of wearing a hijab for women or wearing a kufiyah for men on person perception. In an online experiment, we asked participants to repeatedly rate a target person shown in a public place regarding the target person's character. We varied whether the person wore a headscarf or not to address two research questions: First, does the attitude toward the specific group (here: Muslims) influence sympathy toward and perceived attractiveness of people wearing a "symbol"

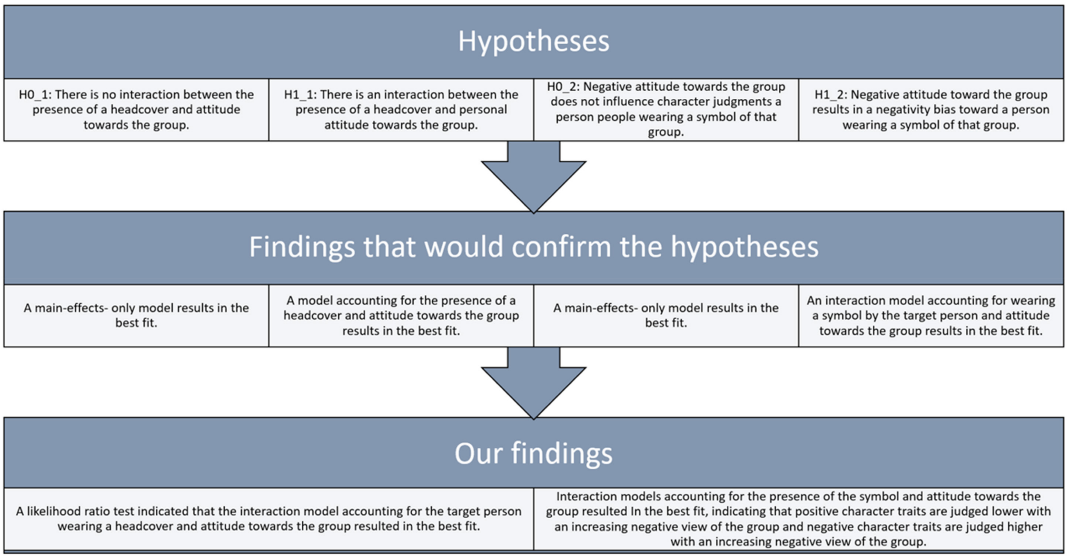

FIGURE 5
Hypotheses, predicted observations, and findings for experiment 2.

(here: wearing paraphernalia referring to Muslim culture) representative of that group? We hypothesize an interaction of head cover (yes vs. no) and personal attitude toward the group (continuous). The interaction is driven by the simple effect that the person wearing a head cover is judged less attractive and less liked with the perceivers' increasing negative attitude toward the group. Second, does a negative attitude toward the specific group result in a negative bias toward a person wearing a headcover? We tested the following hypotheses. Positive character traits are judged lower with an increasingly negative view of the group. Negative character traits are judged higher with increasing negative views of the group. For Experiment 2, hypotheses and findings are summarised in **Figure 5**.

Method

Sample and design

All materials and the preregistration, which were submitted before the study was started, are available at https://osf.io/7mnuv?view_only=64cbd820d23f4bc7b3d84b396ae6c8e4.

The relevant hypothesis for the power analysis, which determined the sample size, was Hypothesis 1 (H1). H1 is an interaction of head cover (yes vs. no) and personal attitude toward the group (continuous). We tested two interaction effects, one for liking and one for attractiveness. We used R package {simR} (Green and Macleod, 2016) for the power calculation on the basis of a random-effects model, accounting for the employed repeated measures design. Detailed model assumptions are explicated in the preregistration. The effect in question is the fixed effect of the interaction between the attitude toward Muslims wearing a hijab/ kufiyah or not and was set to $\beta = 0.15$, which is a small effect. To find that this effect explains a significant amount of variance compared to the main effects only model with $\alpha = 0.01$ and a satisfactory test power $1 - \beta$ of 0.80, we collected data between 18 January 2021 and 1 March 2021 from $N = 114$ ($M_{age} = 35.0$ years, 89 female, 24 male, and 1 other, see **Supplementary Table 2** in the **Electronic supplement D**).

Participants' attitude toward Muslims and Islam was assessed. Participants then were asked to rate a person depicted under varying conditions, which resulted in an orthogonal within-participants design of the varying factors head cover (yes vs. no), target person (male vs. female), and partner (both appear the same way vs. target person differs from other).

Material

Attitude toward group

To assess general attitudes toward foreigners, we used the items of Heitmeyer (2005) assessing attitudes toward foreigners and racism (items 1–4). To measure the specific attitude toward the group (items 5–7), we used the items assessing islamophobia from the "Antidiskriminierungsstelle des Bundes" authorized by the Federal Ministry for Family Affairs, Senior Citizens, Women and Youth (Germany).[1] The responses were measured through a rating scale of 1 (*do not agree*) – 10 (*totally agree*). Items 4, 5, and

1 https://www.antidiskriminierungsstelle.de/SharedDocs/downloads/DE/publikationen/Expertisen/expertise_diskr_aufgrund_islam_religionszugehoerigkeit_sozialwissenschaftlich.pdf?__blob=publicationFile&v=6

TABLE 3 Items for attitude toward group.

No	Item
(1)	The whites are rightly leaders in the world. [Die Weißen sind zu Recht führend in der Welt.]
(2)	Too many foreigners live in Germany. [Es leben zu viele Ausländer in Deutschland.]
(3)	If jobs become scarce, the foreigners living in Germany should be sent back to their homeland. [Wenn Arbeitsplätze knapp werden, sollte man die in Deutschland lebenden Ausländer wieder in ihre Heimat zurückschicken]
(4)	(−) The Muslim culture can fit into our western world. [Die muslimische Kultur passt durchaus in unsere westliche Welt.]
(5)	(−) Islamic and Western European values can be reconciled. [Islamische und westeuropäische Wertvorstellungen lassen sich miteinander vereinbaren.]
(6)	(−) Islam fits perfectly into our western world. [Der Islam passt durchaus in unsere westliche Welt.]
(7)	Aussiedler (people from foreign countries of German origin) should be better off than foreigners because they are of German origin. [Aussiedler (deutschstämmige Ausländer) sollten bessergestellt werden als Ausländer, da sie deutscher Abstammung sind.]

(−) indicate reversed items. Original German wording in brackets.

6 were reversed. We coded items so that a higher score reflects a more positive attitude toward the group (all items are listed in **Table 3**).

We aggregated the responses of all seven items to one scale reflecting a positive attitude toward the group. The score was the mean of all seven responses for each participant. We aimed to reach a Cronbach's $\alpha = 0.7$ and preregistered that all items with a corrected item-total correlation <0.3 would be removed from the scale—in the end, none of the items reached this criterion, so we did not have to remove any data. The scale showed good consistency with Cronbach's $\alpha = 0.89$, $M = 8.09$ and $SD = 1.71$.

Social dominance orientation

To measure social dominance orientation, we used the German Version of the 4-item Short Social Dominance Orientation (SSDO; Pratto et al., 2013). This measure was not relevant to the current study.

Stimuli

The photograph used as stimuli showed a small family consisting of two adults and two children. The stimuli were the same as in Experiment 1, the only difference being that the target persons wore hijabs (when female) and kufiyahs (when male) instead of masks (see **Figure 6**).

Dependent variables

The judgment on the character of the target person was measured with a 7-point rating scale (disagree – agree). The character is described in one sentence. The experiment was carried out in German, but the items here are presented in English (the original wording in German is given in parentheses in **Table 4**). All items were measured on a 7-point rating scale (1 = *fully disagree [trifft gar nicht zu]*, 7 = *fully agree [trifft vollkommen zu]*).

Items 15 and 16 are DV for H1. Items 1–8 will be aggregated to a scale reflecting negative character traits, 9–14 positive character traits, and DV for H2. The reliability for the positive character traits was measured as Rcn = 0.52 and for negative character traits as Rcn = 0.38.

After responding to all pictures, we assessed the participants' opinion about how representative a head cover is for the group by asking: The [picture of the clothing item] is a characteristic of people who consider themselves Muslims. [Das [Bild vom Kleidungsstück] ist ein Merkmal für Menschen, die dem Islam

FIGURE 6
Stimuli used in experiment 2. The figure shows all variations for the male target person. For the female target person, the arrow was moved above the female. To ensure the anonymity of the people displayed in the photograph, faces were blurred for the published manuscript. The original photo (without head cover and blurring effects) was kindly made public by Jason Pier through CC BY-NC 2.0 license.

TABLE 4 Items measuring how the participant perceives the target person.

No	Item
(1)	The person thinks of herself first. [Die Person denkt zuerst an sich selbst.]
(2)	The person is calculating. [Die Person ist berechnend.]
(3)	The person is neurotic. [Die Person ist neurotisch.]
(4)	The person is aggressive. [Die Person ist aggressiv.]
(5)	The person is dangerous. [Die Person ist gefährlich.]
(6)	The person is a cynic. [Die Person ist zynisch]
(7)	The person is lazy. [Die Person ist faul.]
(8)	The person is arrogant. [Die Person ist arrogant.]
(9)	The person is very prosocial. [Die Person ist sehr prosozial.]
(10)	The person is balanced. [Die Person ist ausgeglichen.]
(11)	The person is concerned for others. [Die Person denkt an andere.]
(12)	The person is careful. [Die Person ist umsichtig.]
(13)	The person is trustworthy. [Die Person ist vertrauenswürdig.]
(14)	The person is industrious. [Die Person ist fleissig.]
(15)	The person is attractive. [Die Person ist attraktiv.]
(16)	The person is liked by me. [Die Person ist mir sympathisch.]

Here the English translation is shown. Original German wording in brackets.

angehören]. The responses were measured on a rating scale of 1 (*do not agree*) – 10 (*totally agree*).

Procedure

The procedure was the same as in Experiment 1.

Statistical analysis

We used linear multilevel regressions with participants' ID as a random effect to account for the repeated measures. For the analysis, we mean-centered the variable attitude toward the group and all factorial variables were dummy-coded. For multilevel linear regressions, we used the R package {lmer} (Bates et al., 2015). For analysis of slopes, we used {interactions} (Long, 2019). Because treating ordinal responses as continuous can result in wrong inferences (Liddell and Kruschke, 2018), we also report results based on an ordinal regression in a Bayesian framework in **Electronic supplement F**. In the present study, the results were robust.

Outliers and exclusions

As preregistered, we ran the analysis with the full data set. We carried out a second analysis in which we excluded participants who responded with a rating lower than 5 to the question: The—showing the picture of the clothing item—is a characteristic of people who consider themselves Muslims [Das—showing the picture of the clothing item—ist ein Merkmal für Menschen die dem Islam angehören]. The responses are measured on a rating scale of 1 (*do not agree*)—10 (*totally agree*). Because this would indicate that the participant does not associate a head cover with Muslim culture.

Deviations from the preregistration

We made a mistake in the analysis section. Our Hypothesis 2 is about positive and negative characteristics. In an earlier version, we had written aggression, prosociality, and self-interest. We also missed changing this in the analysis section.

We planned to carry out regressions for two distribution families: Gaussian and cumulative probit in a Bayesian framework and a frequentist framework. However, the ordinal model in a frequentist framework did not converge. For this reason, we decided to only fit the Bayesian models in the robustness check.

We assumed a homogeneous sample. However, inspecting the data shows that some participants show very extreme values in their responses on the scale measuring the attitude toward the group. Linear regression assumes a homogeneous sample and is biased by extreme values in the predictor variable, for this reason, we winsorized these values to –2 SDs for the centered variable.

Results

Test of preregistered hypothesis H1

We observed that perceived attractiveness and liking were dependent on the participants' attitude toward measuring the group and whether the target person was wearing a head cover or not (see **Figure 7**). We fit regression models for attractiveness and liking individually (for all estimates, see **Supplementary Table 7** in the Electronic supplement).

For attractiveness, a likelihood ratio test indicated that the interaction model accounting for wearing a head cover by the target person and attitude toward the group resulted in the best fit compared to the main effects only model, χ^2 (1) = 3.91, p = 0.048, and fixed effects explained 8% of the variance (marg. R^2 = 0.08). Adding the other interactions did not significantly increase fit. In the full factorial model, attractiveness was

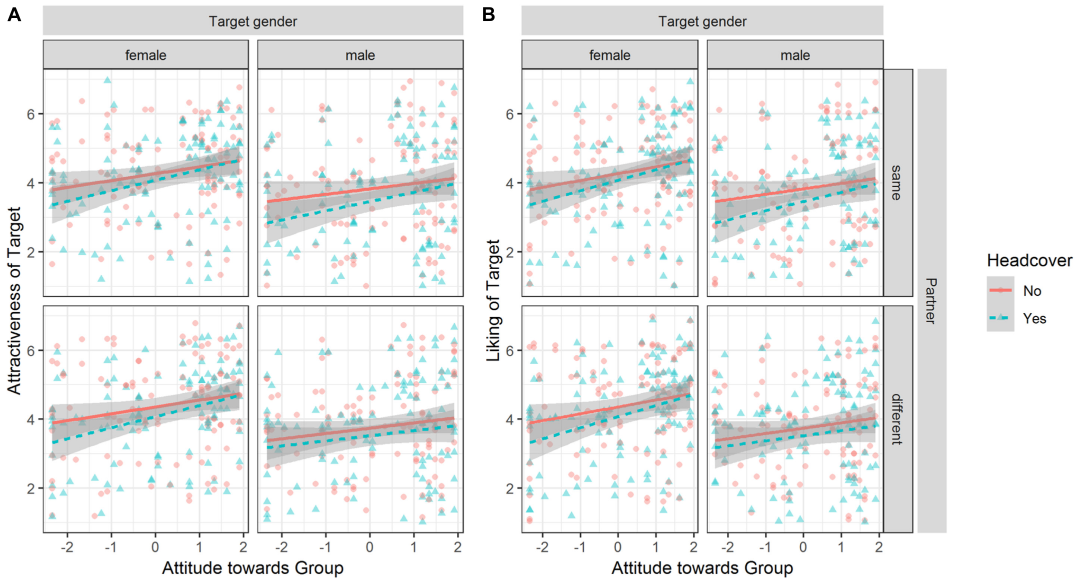

FIGURE 7
Observed attractiveness and liking ratings dependent on attitude, headcover, target person gender, and partner. Plot **(A)** for perceived attractiveness, plot **(B)** for liking. Lines depict linear regression of Y on X and the shaded areas show the 95% CI of the estimate. Points are jittered to avoid overlap.

significantly positively affected by the attitude toward the group, β = 0.20, 95% CI [0.05, 0.35], and significantly decreased when the target person was male compared to a female target person, β = −0.19, 95% CI [−0.22, −0.15]. The moderation effect of the attitude toward the group was not significant, β = 0.11, 95% CI [−0.06, 0.27].

For liking, a likelihood ratio test indicated that the interaction model accounting for wearing a head cover by the target person and attitude toward the group resulted in the best fit compared to the main effects only model, χ^2 (1) = 13.68, $p < 0.001$, and fixed effects explained 18% of the variance (marg. $R^2 = 0.18$). Adding the other interactions did not significantly increase fit. In the full factorial model, liking was significantly positively affected by the attitude toward the group, β = 0.40, 95% CI [0.27, 0.52], and significantly decreased when the target person wore a headcover compared to no headcover, β = −0.11, 95% CI [−0.15, −0.07]. This effect was moderated by the attitude toward the group, β = 0.08, 95% CI [0.04, 0.12]. To test in which regions the slopes differ, we used the Johnson-Neyman procedure. When the moderator value, i.e., the attitude toward the group, was below the interval [0.72, 89.21], the liking of the target person was significantly lower when wearing a headcover than when wearing no headcover.

Test of preregistered hypothesis H2

We observed that wearing a headcover influenced positive and negative character judgments dependent on the perceiver's attitude toward the group (see **Figure 8**). We fit regression models for negative and positive character judgments individually (for all estimates, see **Supplementary Table 8** in the Electronic supplement).

For negative character judgment, a likelihood ratio test indicated that the interaction model accounting for wearing a headcover by the target person and attitude toward the group resulted in the best fit compared to the main effects only model, χ^2 (1) = 8.21, $p = 0.004$, and fixed effects explained 7% of the variance (marg. $R^2 = 0.07$). Adding the other interactions did not significantly increase fit. The effect of wearing a headcover on negative character judgment, β = 0.03, 95% CI [−0.00, 0.06], was moderated by the attitude toward the group, β = −0.04, 95% CI [−0.07, −0.01]. To assess in which regions the slopes differ, we used the Johnson-Neyman procedure. When the moderator value of the attitude toward the group was below the interval [−0.55, 8.3], the judgments of the negative character of the target person were significantly higher when wearing a headcover than when wearing no headcover.

For positive character, a likelihood ratio test indicated that the interaction model accounting for wearing a headcover by the target person and attitude toward the group resulted in the best fit compared to the main effects only model, χ^2 (1) = 19.64, $p < 0.001$, and fixed effects explained 26% of the variance (marg. $R^2 = 0.26$). Adding the other interactions did not significantly increase fit. The effect of wearing a headcover on positive character judgment, β = −0.07, 95% CI [−0.10, −0.04], was moderated by the attitude toward the group, β = 0.07, 95% CI [0.04, 0.10]. When the moderator value of the

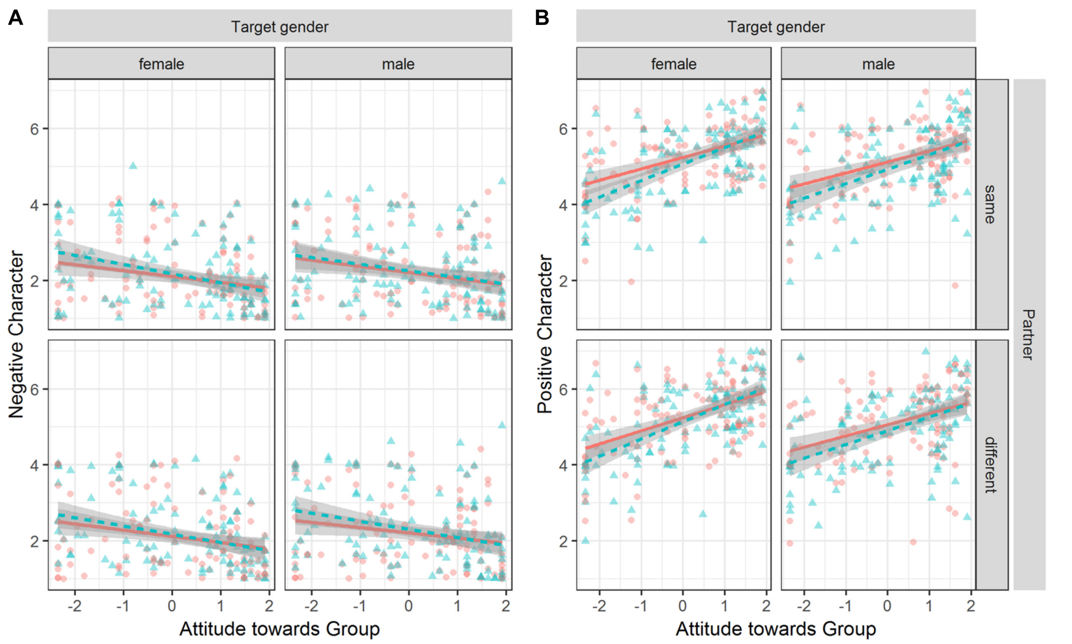

FIGURE 8
Observed positive and negative character judgments dependent on attitude, head cover, target person gender, and partner. Plot **(A)** for negative character judgments. Plot **(B)** for positive character judgments. Lines depict linear regression of Y on X; the shaded areas show the 95% CI of the estimate. Points are jittered to avoid overlap.

attitude toward the group was below the interval [0.36, 3.96], the judgments of the positive character of the target person were significantly lower when wearing a headcover than when wearing no headcover.

Robustness check

Ordinal Bayesian regression

To check the robustness of our results, we used a Bayesian analysis for ordinal linear regression. The detailed results can be found in **Electronic supplement F**. To test H1, we fit an ordinal multilevel model with data clustered in cases using a cumulative-probit distribution. For H1 regarding liking and attractiveness, the results show that the effects were of similar size and the same direction and an 83% HDI for liking [75% HDI for attractive] of the odds ratio of the interaction of wearing a headcover and attitude toward the group were smaller [greater] than 1. When attitude toward the group is negative, then a target person wearing a headcover receives lower ratings than when wearing no headcover.

To test H2, we fit an ordinal multilevel model with data clustered in cases and items using a cumulative-probit distribution. For H2 regarding negative and positive character, the results show that the effects were of similar size and the same direction as in the main analyses. A 95% HDI for the negative character [positive character] of the odds ratio of the interaction of wearing a headcover and attitude toward the group was smaller [greater] than 1. For negative character judgments, when the attitude toward the group is negative, a target person wearing a headcover receives higher ratings than when wearing no headcover; this effect decreases with increasing attitude toward the group. For a positive character judgment, when the attitude toward the group decreases, a target person wearing a headcover receives lower ratings than when wearing no headcover.

For all judgments, the effect of the difference between wearing a headcover or not decreases with increasing attitude toward the group.

Data exclusion

Based on the exclusion criteria, the perception of the head cover as paraphernalia of Muslim culture had to rate 5 for male and female headcovers, n = 32 participants had to be excluded. Re-running all our analyses showed that in the linear regressions, only the interaction of the attitude toward the group with wearing the headcover on the judgment of positive character did not include zero for the 95% CIs for the linear regression. For all other judgments, the effects were not robust in terms of statistical significance. However, the direction and size of the effects matched the full sample (see Electronic supplement G).

For the ordinal cumulative-probit regression, the size and directions of the effects were similar to the full sample, but the 95% Credible Intervals increased for attractiveness. The interaction effect postulated in H1 had a 78% HDI for liking and an 83% HDI for attractiveness for the odds ratio smaller than 1 for the interaction of wearing a headcover and attitude toward the group. For negative and positive character judgments, the effect postulated in H2 had 93% HDI of odds ratio being smaller than 1 for the negative and 95% HDI for odds ratio being larger than 1 for the positive character judgment.

Taken together, the exclusion of participants who did not perceive the headcovers as specific to the group did not alter the size or direction of effects, but it increased the uncertainty about the parameter estimates.

Discussion

In two preregistered online studies, we examined the effect of facial coverings on person perception and judgment. In one study, we examined medical masks, and in a second study, we examined the effect of headcovers. We found that participants' judgments of the person wearing the facial covering relied on the participants' attitude toward issues associated with the facial covering, that is, its' symbolic meaning. We revealed that this interaction effect occurs when wearing a face mask as well as wearing a headcover associated with Islam.

In both studies, we presented photographs of individuals in a day-to-day situation and asked participants to judge them along different dimensions (attractiveness, liking, and character). We varied the visual presentation of the individuals in the pictures by experimentally adding a facial mask typically associated with the context of a pandemic like COVID-19 (Experiment 1) or a headcover (stereo) typically associated with Muslim cultures (Experiment 2) to the faces. In Experiment 1, we measured participants' attitudes toward COVID-19 (the COVID-19 pandemic was still relatively new, and many preventative measures were still active, therefore participants' attitudes toward it were easily accessible to them as they ruled their daily lives), and in Experiment 2, we measured participants' prejudice against Islam. In both studies, the judgments of individuals were altered depending on whether the target persons wore the respective facial covering and the participant's attitude. Furthermore, we observed that the effect of masks on the judgment of the target person was stronger than the effect of wearing a head covering. This difference might be explained by the salience of the attitude associated with the facial covering. During data acquisition, the COVID-19 pandemic was on people's minds resulting in high salience of attitudes that favor and oppose masks. On the other hand, the attitude toward individuals with Muslim backgrounds might have been less important to most people as this was not a focus topic of daily politics when the studies were conducted.

By showing that the same mechanism influences judgments of people wearing facial masks and people wearing head covers, we can generalize the effect of face covers on a person's perception to more general processes underlying social cognition. Judgments are dependent on cues and the valuation of specific cues. And these cues are in the eye of the beholder, which is apparent in the large body of research showing the effect of stereotypes on person perception (Macrae and Bodenhausen, 2000).

Our hypotheses were derived from theories of social cognition and proposed that the attitude of the perceiver, together with the appearance of the human target person, determines the resulting judgments. Our studies resolve inconsistent results in the literature, e.g., that people wearing medical masks are judged more positively among students in some samples (Oldmeadow and Koch, 2021; Hies and Lewis, 2022) but more negatively in other student samples (Miyazaki and Kawahara, 2016). These seemingly contradicting results might be attributed to a further factor that was not considered before: the perceivers' attitudes associated with wearing masks. Including a variable on the perceiver level allows us to frame the whole resulting pattern within a general theory of person perception. This highlights that perceptions and judgments of individuals rely on top-down information processing (Macrae and Bodenhausen, 2000), in the present experiments triggered by the associations held by the perceivers with certain head covers.

Limitations and future research

Before generalizing these findings, important boundaries must be considered.

First, the judgment of the target persons did not matter to the participants. For this reason, participants might be more likely to use heuristic information processing (Pendry and Macrae, 1994), potentially rendering the personal attitude toward the facial covering more powerful. However, when people are facing strangers in everyday life, they also might not be motivated to process information carefully.

Second, the judgment task was highly artificial in that pictures were used and not a real interaction. The pictures were constructed by directly manipulating the appearance of the target persons. The judgment of the target persons was based on reported ratings and could have been influenced by social desirability.

Third, while experiments studying the effects on attractiveness usually utilize frontal pictures in the foreground, a landmark paper from 2007 showed that face and body attractiveness may convey different, and potentially independent, signals about an individual's mate quality (Peters et al., 2007). In our study, we also have to take into account the esthetic properties of the clothes, and certainly, the esthetics of the head (or face) covers. From very recent face mask research, we do know that face masks modulate the attractiveness of faces as such, most generally, unattractive faces seem to benefit from covering the lower half of the face (Pazhoohi et al., 2021). Similar effects are to be expected with headcovers where covered parts of the head which are less attractive might boost the overall attractiveness of a face. Analogously, we could expect similar effects for covering less attractive body parts which might lead to the imagination of a whole body that is more attractive. Indications for this idea stem from research about veiled and non-veiled bodies and the degree of body-(dis)satisfaction (Wilhelm et al., 2018). Future research should explore how the different foci and perspectives used in the stimuli themselves influence person perception.

Fourth, as pointed out in the introduction, the perceived similarity is a strong predictor of liking and perceived attractiveness—while we aimed to manipulate attitude similarity, we did not measure perceived similarity, which would have functioned as a manipulation check. We decided not to use this measure to avoid demand effects; however, future research could replicate our experiments and additionally measure perceived similarity and test if our observed effects are explained through this process.

Finally, the participation was voluntary, and therefore the sample is not representative of the general population—which could have influenced the results. For example, individuals holding strong negative attitudes against COVID-19 or Muslims might not be willing to participate in research studies.

Conclusion

Our results suggest that participants in our study did not judge the person depicted in the picture but judged the head covering and communicated their attitude toward its symbolic meaning. This suggests that the constructed representation of the person perceived could be more strongly influenced by cues and their associations, the stronger the attitude of the perceivers. This deeper consideration also explains why some people become aggressive with people wearing masks while others become relaxed and feel safe when attending to such persons—or react neutrally. Likewise, it explains why some people start to aggressively tear down others' head covers while other observers' imaginations of hospitality and warmth of Muslim cultures are triggered by the same symbol that is torn down by others. In the end, our assessments of others' values, properties, and traits are deeply rooted in free associations emerging non-consciously which can hardly be controlled by the perceiver (see Ortlieb et al., 2020). To sum up, the present studies show that it is important to not only ask if and how certain face covers affect a person's perception, but we should also ask what attitude the perceivers hold toward the facial covering's symbolic meaning and linked associations.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/g8b75/.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JL and C-CC conceived and implemented the experiments. JL analyzed and curated the data. JL and LK wrote the first draft of the manuscript. All authors revised the manuscript, contributed to the article, and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnins.2022.988546/full#supplementary-material

References

Bagnis, A., Celeghin, A., Diano, M., Mendez, C. A., Spadaro, G., Mosso, C. O., et al. (2020). Functional neuroanatomy of racial categorization from visual perception: A meta-analytic study. *Neuroimage* 217:116939. doi: 10.1016/j.neuroimage.2020.116939

Bates, D., Mächler, M., Bolker, B., and Walker, S. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Blair, I. V. (2002). The malleability of automatic stereotypes and prejudice. *Pers. Soc. Psychol. Rev.* 6, 242–261. doi: 10.1207/S15327957PSPR0603_8

Byrne, D., and Griffitt, W. (1973). Interpersonal attraction. *Annu. Rev. Psychol.* 24, 317–336. doi: 10.1146/annurev.ps.24.020173.001533

Carbon, C. C., Faerber, S. J., Augustin, M. D., Mitterer, B., and Hutzler, F. (2018). First gender, then attractiveness: Indications of gender-specific attractiveness processing *via* ERP onsets. *Neurosci. Lett.* 686, 186–192. doi: 10.1016/j.neulet.2018.09.009

Carbon, C. C., Grüter, T., Grüter, M., Weber, J. E., and Lueschow, A. (2010). Dissociation of facial attractiveness and distinctiveness processing in congenital prosopagnosia. *Vis. Cogn.* 18, 641–654. doi: 10.1080/13506280903462471

Desai, S. D., and Kouchaki, M. (2017). Moral symbols: A necklace of garlic against unethical requests. *Acad. Manage. J.* 60, 7–28. doi: 10.5465/amj.2015.0008

Devine, D. J., and Caughlin, D. E. (2014). Do they matter? A meta-analytic investigation of individual characteristics and guilt judgments. *Psychol. Public Policy Law* 20, 109–134. doi: 10.1037/law0000006

Freeman, J. B., and Johnson, K. L. (2016). More than meets the eye: Split-second social perception. *Trends Cogn. Sci.* 20, 362–374. doi: 10.1016/j.tics.2016.03.003

Garcia, S. M., Weaver, K., and Chen, P. (2019). The status signals paradox. *Soc. Psychol. Pers. Sci.* 10, 690–696. doi: 10.1177/1948550618783712

Green, P., and Macleod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods Ecol. Evol.* 7, 493–498. doi: 10.1111/2041-210X.12504

Greiner, B. (2015). Subject pool recruitment procedures: Organizing experiments with ORSEE. *J. Econ. Sci. Assoc.* 1, 114–125. doi: 10.1007/s40881-015-0004-4

Günaydin, G., Zayas, V., Selcuk, E., and Hazan, C. (2012). I like you but I don't know why: Objective facial resemblance to significant others influences snap judgments. *J. Exp. Soc. Psychol.* 48, 350–353. doi: 10.1016/j.jesp.2011.06.001

Harsányi, G., and Carbon, C. C. (2015). How perception affects racial categorization: On the influence of initial visual exposure on labelling people as diverse individuals or racial subjects. *Perception* 44, 100–102. doi: 10.1068/p7854

Heitmeyer, W. (2005). Gruppenbezogene Menschenfeindlichkeit: Die theoretische Konzeption und erste empirische Ergebnisse aus 2002, 2003 und 2004. *Berl. Forum Gewaltprävention* 20, 5–20.

Hies, O., and Lewis, M. B. (2022). Beyond the beauty of occlusion: Medical masks increase facial attractiveness more than other face coverings. *Cogn. Res. Princ. Implic.* 7:1. doi: 10.1186/s41235-021-00351-9

Hönekopp, J. (2006). Once more: Is beauty in the eye of the beholder? Relative contributions of private and shared taste to judgments of facial attractiveness. *J. Exp. Psychol. Hum. Percept. Perform.* 32, 199–209. doi: 10.1037/0096-1523.32.2.199

Hugenberg, K., and Sacco, D. F. (2008). Social categorization and stereotyping: How social categorization biases person perception and face memory. *Soc. Pers. Psychol. Compass* 2, 1052–1072. doi: 10.1111/j.1751-9004.2008.00090.x

Koch, A. J., D'Mello, S. D., and Sackett, P. R. (2015). A meta-analysis of gender stereotypes and bias in experimental simulations of employment decision making. *J. Appl. Psychol.* 100, 128–161. doi: 10.1037/a0036734

Kraus, M. W., and Chen, S. (2010). Facial-feature resemblance elicits the transference effect. *Psychol. Sci.* 21, 518–522. doi: 10.1177/0956797610364949

Langlois, J. H., Kalakanis, L., Rubenstein, A. J., Larson, A., Hallam, M., and Smoot, M. (2000). Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychol. Bull.* 126, 390–414. doi: 10.1037/0033-2909.126.3.390

Liddell, T. M., and Kruschke, J. K. (2018). Analyzing ordinal data with metric models: What could possibly go wrong? *J. Exp. Soc. Psychol.* 79, 328–348. doi: 10.1016/j.jesp.2018.08.009

Long, J. A. (2019). *interactions: Comprehensive, user-friendly toolkit for probing interactions. R package version 1.1.0*. Available online at: https://cran.r-project.org/package=interactions (accessed September 12, 2022).

Macrae, C. N., and Bodenhausen, G. V. (2000). Social cognition: Thinking categorically about others. *Annu. Rev. Psychol.* 51, 93–120. doi: 10.1146/annurev.psych.51.1.93

Maddox, K. B. (2004). Perspectives on racial phenotypicality bias. *Pers. Soc. Psychol. Rev.* 8, 383–401. doi: 10.1207/s15327957pspr0804_4

Maddox, K. B., and Gray, S. A. (2002). Cognitive representations of black Americans: Reexploring the role of skin tone. *Pers. Soc. Psychol. Bull.* 28, 250–259. doi: 10.1177/0146167202282010

Mazzella, R., and Feingold, A. (1994). Socioeconomic status, and gender of defendants and victims on judgments of mock jurors: A meta-analysis. *J. Appl. Soc. Psychol.* 24, 1315–1344.

Mitchell, T. L., Haw, R. M., Pfeifer, J. E., and Meissner, C. A. (2005). Racial bias in mock juror decision-making: A meta-analytic review of defendant treatment. *Law Hum. Behav.* 29, 621–637. doi: 10.1007/s10979-005-8122-9

Miyazaki, Y., and Kawahara, J. I. (2016). The sanitary-mask effect on perceived facial attractiveness. *Jpn. Psychol. Res.* 58, 261–272. doi: 10.1111/jpr.12116

Montoya, R. M., Horton, R. S., and Kirchner, J. (2008). Is actual similarity necessary for attraction? A meta-analysis of actual and perceived similarity. *J. Soc. Pers. Relat.* 25, 889–922. doi: 10.1177/0265407508096700

Oldmeadow, J. A., and Koch, C. (2021). Effects of face masks on person perception. *Perception* 50, 876–889. doi: 10.1177/03010066211045172

Ortlieb, S. A., Kügel, W. A., and Carbon, C. C. (2020). Fechner (1866): The aesthetic association principle—a commented translation. *Iperception* 11:2041669520920309. doi: 10.1177/2041669520920309

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Pendry, L. F., and Macrae, C. N. (1994). Stereotypes and mental life: The case of the motivated but thwarted tactician. *J. Exp. Soc. Psychol.* 30, 303–325. doi: 10.1006/jesp.1994.1015

Peters, M., Rhodes, G., and Simmons, L. W. (2007). Contributions of the face and body to overall attractiveness. *Anim. Behav.* 73, 937–942. doi: 10.1016/j.anbehav.2006.07.012

Peterson, R. A., and Brown, S. P. (2005). On the use of beta coefficients in meta-analysis. *J. Appl. Psychol.* 90, 175–181. doi: 10.1037/0021-9010.90.1.175

Piacentini, M., and Mailer, G. (2004). Symbolic consumption in teenagers' clothing choices. *J. Consum. Behav.* 3, 251–262. doi: 10.1002/cb.138

Pilkington, N. W., and Lydon, J. E. (1997). The relative effect of attitude similarity and attitude dissimilarity on interpersonal attraction: Investigating the moderating roles of prejudice and group membership. *Pers. Soc. Psychol. Bull.* 23, 107–122. doi: 10.1177/0146167297232001

Pratto, F., Çidam, A., Stewart, A. L., Zeineddine, F. B., Aranda, M., Aiello, A., et al. (2013). Social dominance in context and in individuals: Contextual moderation of robust effects of social dominance orientation in 15 languages and 20 countries. *Soc. Psychol. Pers. Sci.* 4, 587–599. doi: 10.1177/1948550612473663

Quinn, K. A., and Macrae, C. N. (2011). The face and person perception: Insights from social cognition. *Br. J. Psychol.* 102, 849–867. doi: 10.1111/j.2044-8295.2011.02030.x

Revelle, W. (2019). "psych: Procedures for personality and psychological research," in *R package published through CRAN (R package version 1.9.12)* (Evanston, IL: NorthwesternUniversity). Available online at: https://cran.r-project.org/package=psych (accessed September 12, 2022).

Shrout, P. E., and Lane, S. P. (2013). "Psychometrics," in *Handbook of research methods for studying daily life*, eds M. R. Mehl and T. S. Conner (New York, NY: Guilford Press).

Singh, R., Ho, L. J., Tan, H. L., and Bell, P. A. (2007). Attitudes, personal evaluations, cognitive evaluation and interpersonal attraction: On the direct, indirect and reverse-causal effects. *Br. J. Soc. Psychol.* 46, 19–42. doi: 10.1348/014466606X104417

Stanley, D. A., Sokol-Hessner, P., Banaji, M. R., and Phelps, E. A. (2011). Implicit race attitudes predict trustworthiness judgments and economic trust decisions. *Proc. Natl. Acad. Sci. U.S.A.* 108, 7710–7715. doi: 10.1073/pnas.1014345108

Synnott, A. (1987). Shame and glory: A sociology of hair. *Br. J. Sociol.* 38, 381–413. doi: 10.2307/590695

Taylor, V. A., Halstead, D., and Haynes, P. J. (2010). Consumer responses to christian religious symbols in advertising. *J. Advert.* 39, 79–92. doi: 10.2753/JOA0091-3367390206

Todorov, A., Olivola, C. Y., Dotsch, R., and Mende-Siedlecki, P. (2014). Social attributions from faces: Determinants, consequences, accuracy, and functional significance. *Annu. Rev. Psychol.* 66, 519–545. doi: 10.1146/annurev-psych-113011-143831

Wheeler, S. C., and Petty, R. E. (2001). The effects of stereotype activation on behavior: A review of possible mechanisms. *Psychol. Bull.* 127, 797–826. doi: 10.1037/0033-2909.127.6.797

Wilhelm, L., Hartmann, A. S., Becker, J. C., Kişi, M., Waldorf, M., and Vocks, S. (2018). Body covering and body image: A comparison of veiled and unveiled Muslim women, Christian women, and atheist women regarding body checking, body dissatisfaction, and eating disorder symptoms. *J. Relig. Health* 57, 1808–1828. doi: 10.1007/s10943-018-0585-3

Willis, J., and Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. *Psychol. Sci.* 17, 592–598.

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The influence of face mask on social spaces depends on the behavioral immune system

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Interacting with objects and people requires specifying localized spaces where these interactions can take place. Previous studies suggest that the space for interacting with objects (i.e., the peripersonal space) contributes to defining the space for interacting with people (i.e., personal and interpersonal spaces). Furthermore, situational factors, such as wearing a face mask, have been shown to influence social spaces, but how they influence the relation between action and social spaces and are modulated by individual factors is still not well understood. In this context, the present study investigated the relationship between action peripersonal and social personal and interpersonal spaces in participants approached by male and female virtual characters wearing or not wearing a face mask. We also measured individual factors related to the behavioral immune system, namely willingness to take risks, perceived infectability and germ aversion. The results showed that compared to peripersonal space, personal space was smaller and interpersonal space was larger, but the three spaces were positively correlated. All spaces were altered by gender, being shorter when participants faced female characters. Personal and interpersonal spaces were reduced with virtual characters wearing a face mask, especially in participants highly aversive to risks and germs. Altogether, these findings suggest that the regulation of the social spaces depends on the representation of action peripersonal space, but with an extra margin that is modulated by situational and personal factors in relation to the behavioral immune system.

KEYWORDS

social interaction, reachable space, perceived vulnerability to disease, interpersonal distance, comfort distance judgment, reachability judgment, COVID-19

Introduction

In order to act on objects in the surroundings, the visual and sensorimotor systems must combine their representations of the environment and the body to define an arm-reach space, classically defined as the peripersonal space (PPS, Rizzolatti et al., 1981; Coello and Iachini, 2015, 2021; di Pellegrino and Làdavas, 2015). Based on electrophysiological studies of the monkey brain, the particular aspect of PPS representation was originally pinpointed by Rizzolatti et al. (1981). It was conceived as an interface between the body and the environment contributing to the orientation of attention toward objects that represent potential targets for motor actions, and would thereby serve two essential functions: selecting potential actions toward incentive objects and protecting the body from threatening objects (Fogassi et al., 1996; Graziano and Cooke, 2006; Brozzoli et al., 2011; Coello and Cartaud, 2021). A particularity is that stimuli located in the PPS are coded through multisensory processes (e.g., Rizzolatti et al., 1981; di Pellegrino et al., 1997; Pavani et al., 2000; Makin et al., 2007; Serino et al., 2015), which allow an enhanced perceptual and cognitive processing of those stimuli, and prepare the motor systems to interact with them (Gori et al., 2011; Belardinelli et al., 2018; Blini et al., 2018). This enhanced processing is thought to subtend the selection of approach-avoidance behavior depending on the readiness of the body to interact with appetitive or aversive stimuli (Corr, 2013; Coello et al., 2018; Gigliotti et al., 2021). Accordingly, brain-imaging and brain stimulation studies revealed that objects processing in PPS recruits not only the sensory brain areas (e.g., visual, auditory, and olfactory), but also the sensorimotor areas including the posterior parietal and ventral premotor cortices (Grafton et al., 1997; Chao and Martin, 2000; Cardellicchio et al., 2011; Proverbio, 2012; Bartolo et al., 2014; Wamain et al., 2016). Altogether, these findings support the idea that PPS is an action space represented on the basis of motor information similarly to action execution or observation (Babiloni et al., 1999; Binkofski et al., 1999; Làvadas and Serino, 2008; Medendorp et al., 2011; Finisguerra et al., 2015).

Daily interaction with the environment also implies social stimuli. One key component of social interaction is the regulation of the distance one maintains with others (Hediger, 1950, 1968; Hall, 1966; Coello and Cartaud, 2021). Indeed, early research in ethology revealed that all animals maintain a certain distance from each other in ecological conditions, both within and between species (Hediger, 1950, 1968). Based on these observations, the social psychologist Hall (1966) suggested that every human being is surrounded by a series of bubbles that serve to maintain proper spacing between individuals in a social context, suggesting that inter-individual distances constitute the foundation of natural social interactions. Accordingly, if the inter-individual distance is too wide, it is not suitable for natural social interactions, and if it is too narrow, and thereby violates personal space (PS), it generates discomfort (Sommer, 1959; Hayduk, 1978; Kennedy et al., 2009; Lloyd, 2009). The efficient inter-individual distance or interpersonal space (IPS) thus results from the subtle balance between the need to interact efficiently and a variety of other factors that are driven by approach-avoidance motivations (Argyle and Dean, 1965).

Beyond facilitating social interactions, inter-individual distance regulation seems to be rooted in sensorimotor representations. Indeed, a number of experiments revealed that PS (i.e., the space immediately surrounding the body that cannot be intruded by others without causing discomfort) was related to PPS representation. As evidence, Iachini et al. (2014, 2016) found both spaces to have a similar size and be commonly affected by the nature, age, and gender of the facing stimulus, with spaces being reduced with humans as compared to robots and cylinders, with females as compared to males, and with children as compared to adults. In another study, Iachini et al. (2015) further showed that both spaces were positively correlated to anxiety. These behavioral results were further corroborated by a brain imaging study showing that the frontoparietal areas known to be involved in PPS representation were also activated by PS intrusions (Vieira et al., 2020; in addition to subcortical areas associated with emotion regulation; Kennedy et al., 2009). This spatial coherence between action and social spaces suggested that they share common motor processes (Lloyd, 2009; Coello and Iachini, 2015, 2021). In particular, it has been proposed that the sensorimotor processes of PPS serve as a spatial reference to define social spaces (Coello and Cartaud, 2021). As evidence, Quesque et al. (2017) showed that extending arm length's representation through tool-use increased not only PPS (Canzoneri et al., 2013; Bourgeois et al., 2014) but also PS. However, Patané et al. (2016, 2017) found dissociated effects of tool-use on PPS and PS, suggesting there is no functional overlap between the two spaces. Moreover, most studies investigated the smallest inter-individual distance that is tolerated (PS), leaving aside the inter-individual one would actually maintain (IPS). Hence, the link between action and social spaces, in particular PS and IPS, is still debated and remains to be further investigated.

The COVID-19 pandemic began in China in the fall of 2019 and quickly spread internationally, with today the death toll of more than 521 million people infected and nearly 6.5 million deaths across the world (WHO Health Emergency Dashboard Homepage, May 2022). To slow down the pandemic, governments have taken drastic measures to quickly find a vaccine, but also to adapt human behavior to prevent contamination. In accordance with WHO guidelines, most governments have mandated the use of barrier gestures in social contexts such as regular hand-washing, maintaining an inter-individual distance of 1–2 m, and wearing a medical face mask. Although highly encouraged due to its obvious sanitary impact, wearing a face mask was not immune to social consequences that have only begun to be studied scientifically in the last 2 years, and its interaction with other barrier gestures such as social distancing is still not well understood (Najmi et al., 2021). The earliest study that was performed (i.e., at the end of the first French lockdown period; March–May 2020) showed that PS was much shorter when facing someone wearing a face mask than someone without a face mask (Cartaud et al., 2020). This effect, associated with a higher feeling of trustworthiness, was confirmed in a number of following studies and extended to IPS (Iachini et al., 2021; Lisi et al., 2021; Luckman et al., 2021; Kroczek et al., 2022). Interestingly, the effect of wearing

FIGURE 1
Virtual characters used in the three experimental tasks (male and female characters with a neutral facial expression wearing a face mask or not from the ATHOS database; Cartaud and Coello, 2020).

a face mask on social interactions was found to also alter facial emotion recognition (Carbon, 2020; Bani et al., 2021; Grundmann et al., 2021; Noyes et al., 2021; Cooper et al., 2022; Ramachandra and Longacre, 2022), in adults as in young children (Gori et al., 2021). However, in all these studies the effect of individual characteristics on the regulation of social spaces when interacting with people wearing a face mask was not taken into account. In this respect, the behavioral immune system (BIS; i.e., proactive behavioral mechanisms that inhibit contact with pathogens such as inference of risk of infection, germ aversion and perceived infectability) has been shown to be one of the best predictors of social space: those whose BIS was more reactive preferred to keep larger physical distances in social interactions (Hromatko et al., 2021). Besides this direct impact, the BIS may modulate the effect of face mask on social distance regulation as face mask also aims to decrease exposure to pathogens. According to the homeostatic model proposed by Coello and Cartaud (2021), social spaces are built on the PPS representation plus an extra margin that adapts as a function of the perceived valence of the social stimulus. Hence, face mask (and the associated trust) may influence social PS and IPS by reducing this margin of safety, while leaving PPS unaffected.

In the present study, we investigated the relationship between action and social spaces by requiring participants to perform reachability (probing PPS), comfort (probing IPS), and discomfort (probing PS) distance judgments while facing approaching male and female virtual characters wearing a face mask or not. We further investigated how individual factors related to the BIS, such as willingness to take risks, germ aversion and perceived infectability, modulate the effect of face mask and gender on the different spaces. Due to the shared sensorimotor underpinning of the action and social spaces, and in line with the homeostatic model, we hypothesized a positive correlation between PPS, PS, and IPS as well as a reduction of the social spaces in the presence of a social stimulus wearing a face mask. Furthermore, individuals who perceive themselves as highly infectable, averse to germs and/or are not willing to take risks were expected to perceive social stimuli as more negative (Thiebaut et al., 2021), especially those without a face mask, and therefore to show a stronger effect of face mask on social spaces.

Materials and methods

Participants

Forty students from the Université of Lille [France, 20 females, mean (M) age ± standard deviation (SD) = 22.4 ± 3.4 years] participated in this study. They were all right-handed and had normal or corrected-to-normal vision. A sample size analysis performed in G*Power indicated that at least 34 participants were required to observe an effect characterized by a small effect size (Cohen's $f = 0.15$) and a high-power criterion (0.8) in a 4 × 2 × 2 repeated-measure ANOVA. The research project was approved by the Research Ethics Board of the University of Lille (CESC Lille, Ref. 2021-515-S95).

Task and procedure

The experiment was realized in the laboratory between April and May 2022. Wearing a face mask was not mandatory in France at that time and participants did not wear a face mask during the experiment. Each participant performed three behavioral tasks in virtual reality before completing two questionnaires and evaluating the stimuli. The following behavioral tasks were performed in a counterbalanced order while standing with a response button in the dominant hand and wearing a head-mounted display:

> *Comfort Distance Judgment*. The participants were required to press the response button as soon as the virtual character approaching them was judged at the most comfortable distance to interact with them. Each trial started with the appearance of a virtual character at 300 cm in front of the participants for 500 ms, which then walked toward the participants along the radial sagittal axis at a velocity of 0.75 m/s. Whenever the participants pressed the response button, the virtual character stopped moving and remained still for 1,000 ms before disappearing. The next trial started at a random delay between 800 and 850 ms following the disappearance of the previous virtual character. The task consisted of 24 trials (2 characters' genders × 2 mask conditions × 6 repetitions) and lasted about 3 min. This judgment task was used to assess IPS.

> *Discomfort Distance Judgment*. The same procedure as in the comfort distance judgment was used, except that the participants were required to press the response button as soon as the virtual character approaching them was at a distance that made them feel uncomfortable. This judgment task was used to assess PS.

> *Reachability Distance Judgment*. The same procedure as in the comfort and discomfort distance judgments was used, except that the participants were required to press the response button as soon as they judged being able to tap on the shoulder of the approaching virtual character, without actually performing any movement. This judgment task was used to assess PPS.

The participants then completed the two following questionnaires:

> *Willingness to take risks* [excerpt from the Socio-Economic Panel (SOEP); Goebel et al., 2019] including a question on attitude toward risk in general, and five questions on attitude toward risk in specific domains: car driving, financial matters, leisure and sports, career, trust toward strangers and health. The participants had to indicate their willingness to take risks on an 11-point scale, with 0 indicating complete unwillingness to take risks, and 10 indicating complete willingness to take risks.

> *Perceived Vulnerability to Disease* (PVD; Duncan et al., 2009) consisting of two subscales: (1) Perceived Infectability (7 items), assessing beliefs about one's vulnerability to catching infectious diseases and (2) Germ Aversion (8 items), assessing emotional discomfort in contexts that evoke pathogen transmission. Items were answered on a 7-points Likert scale ranging from "Strongly disagree" to "Strongly agree."

Finally, the participants evaluated the emotional valence, trustworthiness and healthiness of each virtual character used in the behavioral tasks on a continuous scale ranging from 0 ("Very negative" for emotional valence, "Very untrustworthy" for trustworthiness, and "Very sick" for healthiness) to 100 ("Very positive," "Very trustworthy" and "Very healthy").

Apparatus and stimuli

The virtual stimuli were presented, through an HTC Vive Pro head-mounted display, in a virtual room measuring 6 m × 5 m × 3 m, and consisting of a white floor, a gray ceiling and gray walls. The stimuli consisted of four human characters (two males and two females) selected from the ATHOS database (Cartaud and Coello, 2020).[1] We adapted the hair, eye, and clothes' color in order to match them across genders. The characters had a neutral facial expression, looked straight ahead and were presented with and without a face mask (**Figure 1**). The height of the stimuli was adapted so that the eye level of the virtual characters matched the eye level of the participant.

Data analyzes

The data were analyzed using R (version 4.1.0) and R Studio software (version 1.3.1093).

Action and social spaces' extent

To compute the extent of the PPS, PS, and IPS, we averaged for each participant, mask condition, and character's gender, the distance of the visual character at the time of the response in the reachability, discomfort, and comfort distance judgments, respectively. We then compared the different spaces in terms of their average extent and their sensitivity to gender and face mask by entering the extent in a linear mixed model (LMM) including participant as a random intercept, and Space (PPS, PS vs. IPS), Gender (female vs. male), and Mask (unmasked vs. masked) as fixed effects using the *lme4* R package (Bates et al., 2011). We also planned to compute a LMM including Gender and Mask as fixed factors for each task separately in order to

1 https://osf.io/sp938

check whether we replicated the previously reported effect of gender on PS (Iachini et al., 2014, 2016) and of face mask on PS (Cartaud et al., 2020) and IPS (Iachini et al., 2021; Kroczek et al., 2022). In order to investigate how the effect of face mask and gender interact with individual factors, we conducted the same LMM with the score to the Risk or PVD questionnaire as an additional continuous fixed-effect. The model parameters were estimated using the Laplace approximation and were statistically tested using Wald's χ^2. Bonferroni-corrected *post-hoc* pairwise contrasts were performed using the *emmeans* package (Lenth et al., 2019).

Subjective evaluation of the stimuli

We verified that our different stimuli were judged as similar in terms of emotional valence, healthiness, and trustworthiness to (1) ascertain that the effect of gender was not mediated by differences in perceived valence and (2) investigate whether the effect of face mask might be mediated by differences in perceived trustworthiness or healthiness. To do so, we conducted separate repeated-measures ANOVAs on each of the subjective measure (perceived emotional valence, healthiness, and trustworthiness) with Gender (female vs. male) and Face Mask (unmasked vs. masked) as within-subject variables.

Correlation analysis

We then further investigated the relationship between the extent of the different spaces with pairwise correlation analyzes. We computed the Pearson *r* coefficient for each pair of spaces, gender, and face mask conditions. As the results were similar across Gender and Face mask conditions (see details in **Supplementary material**), we reported only the *r* coefficient for each pair of spaces averaged over Gender and Face mask conditions in the main manuscript.

Results

Effect of face mask and gender on action and social spaces

The general LMM on the extent of the different spaces only showed a significant main effect of Space, $\chi^2(2) = 412.10$, $p < 0.001$, $\eta^2 = 0.49$. The average size $\pm$ standard error [*SE*] was 118.9 $\pm$ 3.6 cm for the IPS, 78.4 $\pm$ 2.4 cm for the PPS, and 71.6 $\pm$ 3.3 cm for the PS. *Post-hoc* pairwise comparisons showed that all spaces were significantly different in extent (all *p*-values <0.022; **Figure 2**).

Interpersonal space. The LMM conducted on the extent of IPS showed a main effect of Gender, $\chi^2(1) = 10.32$, $p = 0.001$, $\eta^2 = 0.08$, indicating that females were preferentially placed at shorter distances (116.9 $\pm$ 5.1 cm) than males (121.00 $\pm$ 5.1 cm; **Figure 2**).

Personal space. The LMM on the extent of PS showed a main effect of Gender, $\chi^2(1) = 5.97$, $p = 0.025$, $\eta^2 = 0.05$, indicating that females were tolerated closer (70.3 $\pm$ 4.6 cm) than males (72.84 $\pm$ 4.7 cm; **Figure 2**). There was also a significant effect of Mask, $\chi^2(1) = 5.13$, $p = 0.023$, $\eta^2 = 0.04$, indicating that masked virtual characters were tolerated at a shorter distance (70.4 $\pm$ 4.6 cm) than unmasked ones (72.7 $\pm$ 4.7 cm; **Figure 2**).

Peripersonal space. The LMM showed a significant a main effect of Gender, $\chi^2(1) = 3.96$, $p = 0.046$, $\eta^2 = 0.03$, embedded in a Gender $\times$ Mask interaction, $\chi^2(1) = 5.24$, $p = 0.022$, $\eta^2 = 0.04$. *Post-hoc* pairwise contrasts indicated that females were judged reachable at a shorter distance than males, but only when the characters were unmasked, $t(117) = -3.47$, $p = 0.003$, and not when they were masked, $t(117) = 0.211$, $p = 0.832$ (**Figure 2**).

Interaction between spaces and willingness to take risks

Interpersonal space. The LMM conducted on the extent of IPS including Risk as a third fixed effect showed in addition to the main effect of Gender, a significant Risk $\times$ Mask interaction, $\chi^2(1) = 7.90$, $p = 0.004$, $\eta^2 = 0.06$. In particular, individuals who are not willing to take risks preferred to place unmasked characters further away than masked characters, while the reverse was observed in individuals who are willing to take risks (**Figure 3A**).

Personal space. The LMM on PS showed that the effect of Mask was embedded in a significant Mask $\times$ Risk interaction, $\chi^2(1) = 3.98$, $p = 0.046$, $\eta^2 = 0.03$, indicating that individuals that are not willing to take risks felt more quickly discomfortable when facing unmasked than masked characters, while there was no difference in individuals who are willing to take risks (**Figure 3B**).

Peripersonal space. The LMM showed no main effect of Risk or any interaction with the other fixed effects.

Interaction between spaces and perceived vulnerability to disease

Interpersonal space. The LMM conducted on the extent of IPS including PVD as a third fixed effect showed no effect of PVD and no interaction with the other effects. However, when adding the score to the subscales rather than the total score as an additional fixed effect, there was a significant Mask $\times$ Germ Aversion interaction, $\chi^2(1) = 3.90$, $p = 0.048$, $\eta^2 = 0.03$, indicating that individuals with high germ aversion preferentially placed unmasked virtual characters further away than masked virtual characters while no difference to a slight opposite trend was observed in individuals with low germ aversion (**Figure 4A**). There was no significant

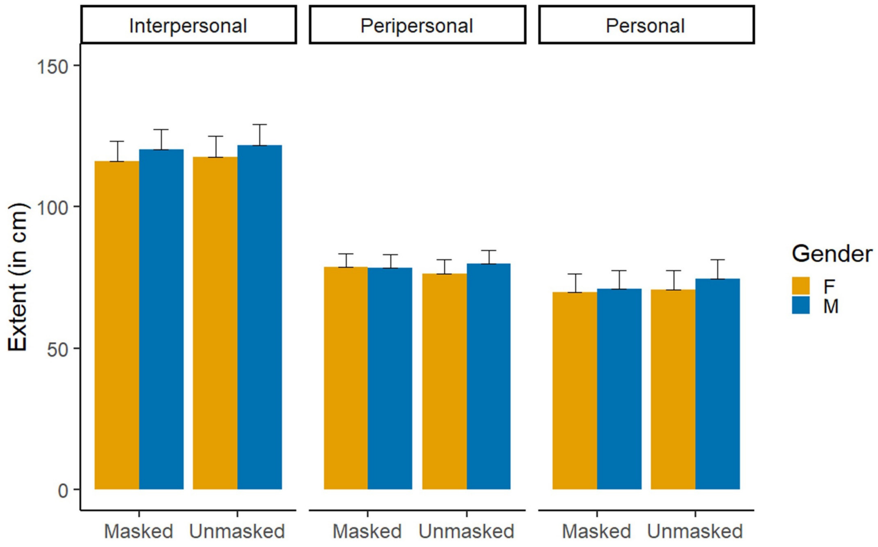

FIGURE 2
Mean interpersonal space (IPS), peripersonal space (PPS), and personal space (PS) when facing male and female characters wearing a face mask or not. Error bars represent the standard errors.

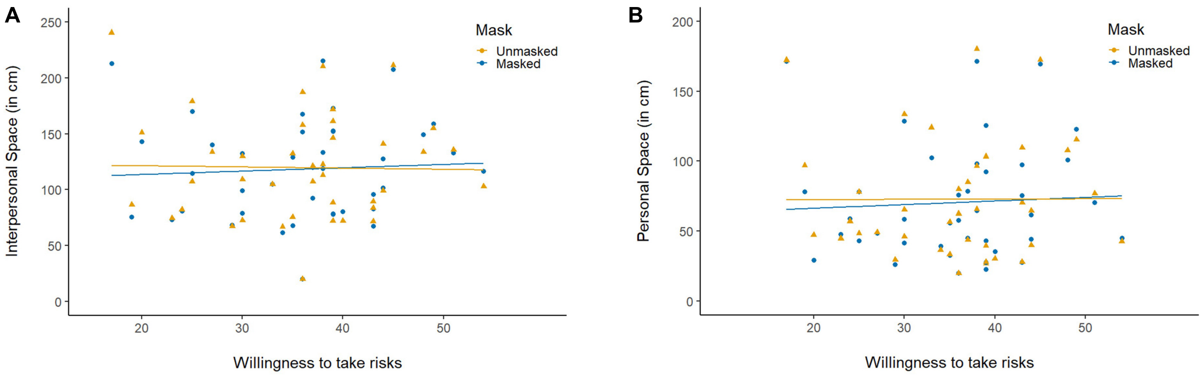

FIGURE 3
The interaction between the effect of the face mask and the willingness to take risks on **(A)** interpersonal space (IPS) and **(B)** personal space (PS).

Mask × Perceived Infectability interaction, $\chi^2(1) = 0.15$, $p = 0.694$, $\eta^2 < 0.01$.

Personal space. The LMM conducted on the extent of PS showed that the main effect of Mask was embedded in a Mask × PVD interaction, $\chi^2(1) = 4.89$, $p = 0.027$, $\eta^2 = 0.04$. The interaction indicates that individuals with high scores on the PVD scale felt more quickly uncomfortable when facing unmasked virtual characters than masked virtual characters, while the reverse was observed in individuals with low PVD scores. When adding the score to the subscales rather than the total score as an additional fixed effect, there was a significant Mask × Germ Aversion interaction, $\chi^2(1) = 7.22$, $p = 0.007$, $\eta^2 = 0.06$, but no Mask × Perceived Infectability interaction, $\chi^2(1) = 0.81$, $p = 0.368$, $\eta^2 = 0.00$, suggesting that the effect was mainly driven by germ aversion (**Figure 4B**).

Peripersonal space. The LMM showed no effect of PVD (either when considering the total score or the score to each subscale) or any interaction with the other fixed effects.

Subjective evaluation of the stimuli

The repeated-measure ANOVAs showed no significant effect of Gender (female vs. male) or Face mask condition (unmasked vs. masked) on perceived healthiness, $F_{Gender}(1, 39) = 0.62$, $p_{Gender} = 0.434$, $\eta^2{}_{Gender} = 0.02$, $F_{Mask}(1, 39) = 1.67$, $p_{Mask} = 0.203$, $\eta^2{}_{Mask} = 0.04$, trust, $F_{Gender}(1, 39) = 0.07$, $p_{Gender} = 0.795$, $\eta^2{}_{Gende} < 0.01$, $F_{Mask}(1, 39) = 2.75$, $p_{Mask} = 0.105$, $\eta^2{}_{Mask} = 0.07$, or perceived emotional valence, $F_{Gender}(1, 39) = 0.70$, $p_{Gender} = 0.409$, $\eta^2{}_{Gender} = 0.02$, $F_{Mask}(1,$

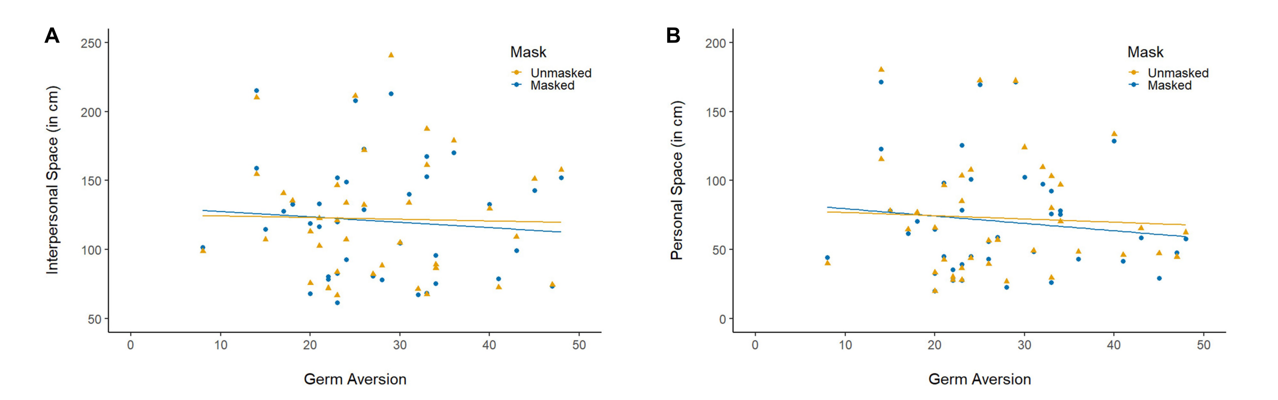

FIGURE 4
The interaction between the effect of the face mask and germ aversion on **(A)** interpersonal space (IPS) and **(B)** personal space (PS).

39) = 2.68, p_{Mask} = 0.109, $\eta^2{}_{Mask}$ = 0.06. There was, however, a significant interaction between Face mask and Gender on the perceived emotional valence, $F(1, 39) = 9.13$, $p = 0.004$, $\eta^2{}_{Mask} = 0.19$. *Post-hoc* paired *t*-test (corrected with Bonferroni) further indicated that unmasked male characters were perceived noticeably more negative ($M \pm SE = 48.84 \pm 2.28$) than masked male characters (53.96 ± 2.25), $t(39) = 2.31$, $p = 0.024$, while there was no difference between the masked (54.22 ± 2.43) and unmasked (56.20 ± 2.45) female characters.

Correlation between peripersonal space, personal space, and interpersonal space

All three spaces were positively correlated to each other in all stimuli (i.e., female unmasked, female masked, male unmasked, and male masked; see details in **Supplementary material**). The Pearson *r* coefficients averaged over Gender and Face Mask conditions are reported in **Table 1**.

Discussion

The aim of the present study was to investigate the relationship between the action and social spaces surrounding the body by testing whether they are (1) correlated to each other and (2) similarly impacted by gender and face mask. We further investigated whether individual differences in the BIS modulate the effect of face mask on the different spaces. Our prediction was that if the sensorimotor processes of PPS contribute to the regulation of the social spaces, all three spaces should be positively correlated and be similarly impacted by gender and face mask. Furthermore, the effect of face mask was expected to influence mainly PS and IPS, and to be stronger in individuals with a reactive BIS, and thus with high perceived infectability and high aversion to risks and germs.

TABLE 1 Pearson correlation matrix for the average size of peripersonal space (PPS), personal space (PS) and interpersonal space (IPS).

	Peripersonal	Personal	Interpersonal
Peripersonal	1		
Personal	0.54**	1	
Interpersonal	0.57**	0.68**	1

***P*-value <0.01.

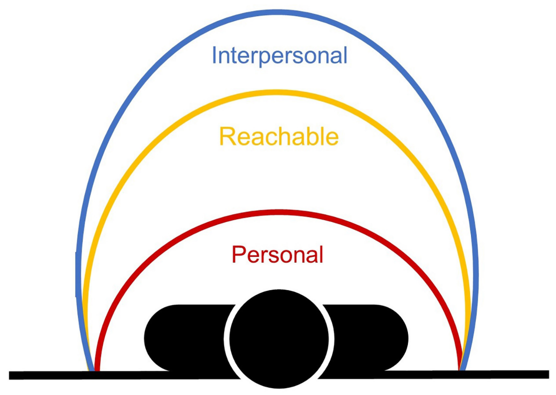

FIGURE 5
Schematic representation of the organization of the different spaces.

The results showed that compared to the PPS (78 cm), PS was smaller (72 cm) and IPS was larger (119 cm). This means that participants preferred placing others at a larger distance than the maximal distance they ought to be able to reach, and felt uncomfortable when others were below this limit (**Figure 5**). These findings are in line with previous observations showing that IPS is typically between 80 and 140 cm (Sorokowska et al., 2017), while PPS and PS are smaller (i.e., 50–70 cm; Ambrosini et al., 2012; Bourgeois et al., 2014; Holt et al., 2014;

Iachini et al., 2016). The present study further highlights that PS was smaller than PPS. The difference was small though, explaining why some previous studies found that the presence of stimuli in PPS generates discomfort together with strong physiological responses (Kennedy et al., 2009; Cartaud et al., 2018, 2020; Ellena et al., 2020; Vieira et al., 2020). Despite the differences in average extent, the three spaces were positively correlated to each other, irrespectively of the gender of the facing virtual character and the presence of a face mask or not. This means that participants who had a large (or small) PPS representation were also those who preferred placing and tolerated others far away (or close). Moreover, PPS and IPS were commonly affected by gender, being shorter when participants interacted with female characters. It is worth noting that the effect of gender on PPS was only observed when the virtual characters were unmasked. We checked whether the effect of the character's gender was similar depending on the gender of the participant and found an overall tendency for closer distances with female characters in both female and male participants (procedure and results reported in the **Supplementy material**). Thus, our results do not only replicate previous findings showing that action and social spaces are commonly affected by gender (Iachini et al., 2014, 2016), but go a step further by showing that they vary together across individuals, at least with virtual characters exhibiting a neutral facial expression. Altogether, these results support the idea that social spaces are rooted in the representation of PPS in relation to its sensorimotor nature, as indexed by the reachability judgments. Accordingly, it is likely that the sensorimotor representation of PPS serves as a spatial reference to specify interpersonal distances in social contexts (Coello and Cartaud, 2021).

Importantly, unmasked characters triggered discomfort already at further distances than masked characters, but face mask did not impact preferred inter-individual distance or reachability judgments at the group level (contrary to what has been previously observed; e.g., Cartaud et al., 2020). The effect of the face mask on both PS and IPS was, however, modulated by risk and germ aversion, with unmasked characters triggering more quickly discomfort and being preferentially placed further away in individuals who are risk and germ averse, while the reverse was observed in participants who are not averse to risk and germs. This supports the idea that the BIS affects inter-individual distances, though not necessarily in a direct way as shown by Hromatko et al. (2021), but also through the modulation of the effect of situational factors, such as the presence of a face mask, on these distances. The BIS is assumed to be triggered by perceptual cues connoting the presence of pathogens in the surrounding environment. These cues can also consist of conspecifics that behave in ways that increase the likelihood that infections will be spread by failing to observe the required sanitary practices. When detecting such cues, the BIS is assumed to react by triggering disgust and aversive cognition, as well as behavioral avoidance (Schaller, 2011). Hence, the presence of a face mask on certain virtual characters might certainly have cued the presence of pathogens in the environment, especially in a context where COVID-19 is still circulating. Thereby, it might have generated behavioral avoidance toward the characters that increased the risk of infection spreading, i.e., those who did not wear a face mask, especially in individuals with high risk and germ aversion, reflecting a reactive BIS. It is worth noting that we cannot exclude that the effects rather reflect approaching mechanisms toward masked characters. However, regarding the pathogens avoidance function of the BIS, it is more likely that high germ and risk aversion causes avoidance of people that are at risk than approach behaviors toward those that are not. The finding that individuals with low risk and germ aversion rather placed and tolerated unmasked characters closer than masked characters might be explained by a natural tendency toward gregariousness in individuals that do not perceive themselves as vulnerable to disease (Schaller, 2011). Nevertheless, these interpretations about how the BIS modulates the effect of the face mask are only speculative at this stage and would need further investigation to be specified.

It is worth underlining that, without considering the BIS, we only found an effect of face mask on PS, while it has been previously reported on both PS and IPS (Cartaud et al., 2020; Iachini et al., 2021; Lisi et al., 2021; Luckman et al., 2021; Kroczek et al., 2022). Moreover, we also failed to replicate the effect of face mask on perceived trustworthiness that was typically reported in these studies. One possible explanation is that the perception of face mask has changed since then. Indeed, the social and cultural meaning of face mask, and thereby the way they are perceived, have changed with their use and recommendation over the first months of the COVID-19 pandemic. For instance, from April to October 2020 face mask progressively switched from "symbol of disease" to "symbol of prevention" (Schönweitz et al., 2022). As most studies were conducted after the first months of the pandemic when face mask already reflected more prevention than disease, it is not surprising they found increased trust toward masked individuals. We collected our data more than two years after the beginning of the pandemic when face mask was not mandatory anymore and contaminations were in constant decrease. Hence, the face mask might only have remained a symbol of prevention to the participants with a reactive BIS. Accordingly, a recent study found only limited effects of face mask on first impressions of others (Twele et al., 2022).

The fact that the PPS was not affected by the face mask nor modulated by the BIS, while social spaces were, is in some aspect in line with the homeostatic theory of social interaction (Coello and Cartaud, 2021). As indicated by the authors, the IPS would be built on the basis of PPS representation with an extra margin that is flexible depending on the context. The authors suggested that this extra margin would adapt as a function of the perceived valence or threat of the social stimulus. Although we did not find evidence for a difference in terms of emotional valence between the masked and unmasked virtual characters, unmasked individuals usually represent a greater risk in terms of pathogen transmission (Aranguren, 2021). Accordingly, the extra margin may increase while interacting with unmasked individuals, in particular for participants showing a reactive BIS, leading to increased social distance while leaving unaffected PPS. The fact that face mask could be associated with risk compensation affecting social distances would require further investigations in the future.

To summarize, the present study highlighted the intrinsic relationship between action PPS and social PS and IPS. Furthermore, it confirmed the previous finding of reduced social spaces in the presence of individuals wearing a face mask. However, several years after the beginning of the pandemic, the effect was turned down probably due to habituation, so it was still observed in individuals characterized by high aversion to risk and germs. In conclusion, the present findings suggest that the regulation of the social spaces depends on the representation of PPS, but with an extra margin that is modulated by situational and personal factors in relation to the BIS.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/serjn/.

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Board of the University of Lille. The patients/participants provided their written informed consent to participate in this study.

Author contributions

LG collected and analyzed the data. Both authors contributed to the design of the study and the writing of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnins.2022.991578/full#supplementary-material

References

Ambrosini, E., Scorolli, C., Borghi, A. M., and Costantini, M. (2012). Which body for embodied cognition? Affordance and language within actual and perceived reaching space. *Conscious. Cogn.* 21, 1551–1557. doi: 10.1016/j.concog.2012.06.010

Aranguren, M. (2021). Face mask use conditionally decreases compliance with physical distancing rules against Covid-19: Gender differences in risk compensation pattern. *Ann. Behav. Med.* 56, 332–346. doi: 10.1093/abm/kaab072

Argyle, M., and Dean, J. (1965). Eye-contact, distance and affiliation. *Sociometry* 28, 289–304. doi: 10.2307/2786027

Babiloni, C., Carducci, F., Cincotti, F., Rossini, P. M., Neuper, C., Pfurtscheller, G., et al. (1999). Human movement-related potentials vs desynchronization of EEG alpha rhythm: A high-resolution EEG study. *Neuroimage* 10, 658–665. doi: 10.1006/nimg.1999.0504

Bani, M., Russo, S., Ardenghi, S., Rampoldi, G., Wickline, V., Nowicki, S., et al. (2021). Behind the mask: Emotion recognition in healthcare students. *Med. Sci. Educat.* 31, 1273–1277. doi: 10.1007/s40670-021-01317-8

Bartolo, A., Coello, Y., Edwards, M. G., Delepoulle, S., Endo, S., and Wing, A. M. (2014). Contribution of the motor system to the perception of reachable space: An fMRI study. *Eur. J. Neurosci.* 40, 3807–3817. doi: 10.1111/ejn.12742

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., et al. (2011). *Package 'lme4'. Linear mixed-effects models using S4 classes. R Package Version* 1. 1–29.

Belardinelli, A., Lohmann, J., Farnè, A., and Butz, M. V. (2018). Mental space maps into the future. *Cognition* 176, 65–73. doi: 10.1016/j.cognition.2018.03.007

Binkofski, F., Buccino, G., Stephan, K. M., Rizzolatti, G., Seitz, R. J., and Freund, H. J. (1999). A parieto-premotor network for object manipulation: Evidence from neuroimaging. *Exp. Brain Res.* 128, 210–213. doi: 10.1007/s002210050838

Blini, E., Desoche, C., Salemme, R., Kabil, A., Hadj-Bouziane, F., and Farnè, A. (2018). Mind the depth: Visual perception of shapes is better in peripersonal space. *Psychol. Sci.* 29, 1868–1877. doi: 10.1177/0956797618795679

Bourgeois, J., Farnè, A., and Coello, Y. (2014). Costs and benefits of tool-use on the perception of reachable space. *Acta Psychol.* 148, 91–95. doi: 10.1016/j.actpsy.2014.01.008

Brozzoli, C., Makin, T. R., Cardinali, L., Holmes, N. P., and Farne, A. (2011). "Eripersonal space: A multisensory interface for body-object interactions," in *The neural bases of multisensory processes*, eds M. M. Murray and M. T. Wallace (London: Taylor and Francis), 449–466. doi: 10.1201/9781439812174-29

Canzoneri, E., Ubaldi, S., Rastelli, V., Finisguerra, A., Bassolino, M., and Serino, A. (2013). Tool-use reshapes the boundaries of body and peripersonal space representations. *Exp. Brain Res.* 228, 25–42. doi: 10.1007/s00221-013-3532-2

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Cardellicchio, P., Sinigaglia, C., and Costantini, M. (2011). The space of affordances: A TMS study. *Neuropsychologia* 49, 1369–1372. doi: 10.1016/j.neuropsychologia.2011.01.021

Cartaud, A., and Coello, Y. (2020). ATHOS: A database of 48 3D Human virtual characters with non-emotional facial expreSsion for virtual reality. *PsyArXiv* [Preprint]. doi: 10.31234/osf.io/r7fby

Cartaud, A., Quesque, F., and Coello, Y. (2020). Wearing a face mask against Covid-19 results in a reduction of social distancing. *PLoS One* 15:e0243023. doi: 10.1371/journal.pone.0243023

Cartaud, A., Ruggiero, G., Ott, L., Iachini, T., and Coello, Y. (2018). Physiological response to facial expressions in peripersonal space determines interpersonal distance in a social interaction context. *Front. Psychol.* 9:657. doi: 10.3389/fpsyg.2018.00657

Chao, L. L., and Martin, A. (2000). Representation of manipulable man-made objects in the dorsal stream. *Neuroimage* 12, 478–484. doi: 10.1006/nimg.2000.0635

Coello, Y., and Cartaud, A. (2021). The interrelation between peripersonal action space and interpersonal social space: Psychophysiological evidence and clinical implications. *Front. Hum. Neurosci.* 15:636124. doi: 10.3389/fnhum.2021.636124

Coello, Y., and Iachini, T. (2015). "Objects and people in space: Towards a unified theoretical framework," in *Foundations of embodied cognition*, eds Y. Coello and M. Fischer (Oxon: Routledge), 198–219.

Coello, Y., and Iachini, T. (2021). "The social dimension of peripersonal space," in *The world at our fingertips: A multidisciplinary exploration of peripersonal space*, eds F. de Vignemont, A. Serino, H. Y. Wong, and A. Farné (Oxford: Oxford University Press), 267–284. doi: 10.1093/oso/9780198851738.003.0015

Coello, Y., Quesque, F., Gigliotti, M. F., Ott, L., and Bruyelle, J. L. (2018). Idiosyncratic representation of peripersonal space depends on the success of one's own motor actions, but also the successful actions of others! *PLoS One* 13:e0196874. doi: 10.1371/journal.pone.0196874

Cooper, H., Brar, A., Beyaztas, H., Jennings, B. J., and Bennetts, R. J. (2022). The effects of face coverings, own-ethnicity biases, and attitudes on emotion recognition. *Cogn. Res. Princ. Implic.* 7:57. doi: 10.1186/s41235-022-00400-x

Corr, P. J. (2013). Approach and avoidance behaviour: Multiple systems and their interactions. *Emot. Rev.* 5, 285–290. doi: 10.1177/1754073913477507

di Pellegrino, G., and Làdavas, E. (2015). Peripersonal space in the brain. *Neuropsychologia* 66, 126–133. doi: 10.1016/j.neuropsychologia.2014.11.011

di Pellegrino, G., Làdavas, E., and Farné, A. (1997). Seeing where your hands are. *Nature* 388:730. doi: 10.1038/41921

Duncan, L. A., Schaller, M., and Park, J. H. (2009). Perceived vulnerability to disease: Development and validation of a 15-item self-report instrument. *Pers. Individ. Differ.* 47, 541–546. doi: 10.1016/j.paid.2009.05.001

Ellena, G., Battaglia, S., and Làdavas, E. (2020). The spatial effect of fearful faces in the autonomic response. *Exp. Brain Res.* 238, 2009–2018. doi: 10.1007/s00221-020-05829-4

Finisguerra, A., Canzoneri, E., Serino, A., Pozzo, T., and Bassolino, M. (2015). Moving sounds within the peripersonal space modulate the motor system. *Neuropsychologia* 70, 421–428. doi: 10.1016/j.neuropsychologia.2014.09.043

Fogassi, L., Gallese, V., Fadiga, L., Luppino, G., Matelli, M., and Rizzolatti, G. (1996). Coding of peripersonal space in inferior premotor cortex (area F4). *J. Neurophysiol.* 76, 141–157. doi: 10.1152/jn.1996.76.1.141

Gigliotti, M. F., Coelho, P. S., Coutinho, J., and Coello, Y. (2021). Peripersonal space in social context is modulated by action reward, but differently in males and females. *Psychol. Res.* 85, 181–194. doi: 10.1007/s00426-019-01242-x

Goebel, J., Grabka, M. M., Liebig, S., Kroh, M., Richter, D., Schröder, C., et al. (2019). The German socio-economic panel (SOEP). *Jahrb. Natl. Ökon. Stat.* 239, 345–360. doi: 10.1515/jbnst-2018-0022

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking emotions: Face masks impair how we read emotions. *Front. Psychol.* 12:669432. doi: 10.3389/fpsyg.2021.669432

Gori, M., Sciutti, A., Burr, D., and Sandini, G. (2011). Direct and indirect haptic calibration of visual size judgments. *PLoS One* 6:e25599. doi: 10.1371/journal.pone.0025599

Grafton, S. T., Fadiga, L., Arbib, M. A., and Rizzolatti, G. (1997). Premotor cortex activation during observation and naming of familiar tools. *Neuroimage* 6, 231–236. doi: 10.1006/nimg.1997.0293

Graziano, M. S., and Cooke, D. F. (2006). Parieto-frontal interactions, personal space, and defensive behavior. *Neuropsychologia* 44, 845–859. doi: 10.1016/j.neuropsychologia.2005.09.009

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hall, E. T. (1966). *The hidden dimension*. New York, NY: Doubleday.

Hayduk, L. A. (1978). Personal space: An evaluative and orienting overview. *Psychol. Bull.* 85, 117–134. doi: 10.1037/0033-2909.85.1.117

Hediger, H. (1950). *Wild animals in captivity*. London: Butterworths.

Hediger, H. (1968). *The psychology and behaviour of animals in zoos and circuses.* New York, NY: Dover Publications.

Holt, D. J., Cassidy, B. S., Yue, X., Rauch, S. L., Boeke, E. A., Nasr, S., et al. (2014). Neural correlates of personal space intrusion. *J. Neurosci.* 34, 4123–4134. doi: 10.1523/JNEUROSCI.0686-13.2014

Hromatko, I., Grus, A., and Kolđeraj, G. (2021). Do islanders have a more reactive behavioral immune system? Social cognitions and preferred interpersonal distances during the COVID-19 pandemic. *Front. Psychol.* 12:647586. doi: 10.3389/fpsyg.2021.647586

Iachini, T., Coello, Y., Frassinetti, F., and Ruggiero, G. (2014). Body space in social interactions: A comparison of reaching and comfort distance in immersive virtual reality. *PLoS One* 9:e111511. doi: 10.1371/journal.pone.0111511

Iachini, T., Coello, Y., Frassinetti, F., Senese, V. P., Galante, F., and Ruggiero, G. (2016). Peripersonal and interpersonal space in virtual and real environments: Effects of gender and age. *J. Environ. Psychol.* 45, 154–164. doi: 10.1016/j.jenvp.2016.01.004

Iachini, T., Frassinetti, F., Ruotolo, F., Sbordone, F. L., Ferrara, A., Arioli, M., et al. (2021). Social distance during the COVID-19 pandemic reflects perceived rather than actual risk. *Int. J. Environ. Res. Public Health* 18:5504. doi: 10.3390/ijerph18115504

Iachini, T., Ruggiero, G., Ruotolo, F., Schiano di Cola, A., and Senese, V. P. (2015). The influence of anxiety and personality factors on comfort and reachability space: A correlational study. *Cogn. Process.* 16, 255–258. doi: 10.1007/s10339-015-0717-6

Kennedy, D. P., Gläscher, J., Tyszka, J. M., and Adolphs, R. (2009). Personal space regulation by the human amygdala. *Nat. Neurosci.* 12, 1226–1227. doi: 10.1038/nn.2381

Kroczek, L. O., Böhme, S., and Mühlberger, A. (2022). Face masks reduce interpersonal distance in virtual reality. *Sci. Rep.* 12:2213. doi: 10.1038/s41598-022-06086-x

Làvadas, E., and Serino, A. (2008). Action-dependent plasticity in peripersonal space representations. *Cogn. Neuropsychol.* 25, 1099–1113. doi: 10.1080/02643290802359113

Lenth, R., Singmann, H., Love, J., Buerkner, P., and Herve, M. (2019). *Package 'emmeans'*.

Lisi, M. P., Scattolin, M., Fusaro, M., and Aglioti, S. M. (2021). A Bayesian approach to reveal the key role of mask wearing in modulating projected interpersonal distance during the first COVID-19 outbreak. *PLoS One* 16:e0255598. doi: 10.1371/journal.pone.0255598

Lloyd, D. M. (2009). The space between us: A neurophilosophical framework for the investigation of human interpersonal space. *Neurosci. Biobehav. Rev.* 33, 297–304. doi: 10.1016/j.neubiorev.2008.09.007

Luckman, A., Zeitoun, H., Isoni, A., Loomes, G., Vlaev, I., Powdthavee, N., et al. (2021). Risk compensation during COVID-19: The impact of face mask usage on social distancing. *J. Exp. Psychol. Appl.* 27, 722–738. doi: 10.1037/xap0000382

Makin, T. R., Holmes, N. P., and Zohary, E. (2007). Is that near my hand? Multisensory representation of peripersonal space in human intraparietal sulcus. *J. Neurosci.* 27, 731–740. doi: 10.1523/JNEUROSCI.3653-06.2007

Medendorp, W. P., Buchholz, V. N., Van Der Werf, J., and Leoné, F. T. (2011). Parietofrontal circuits in goal-oriented behaviour. *Eur. J. Neurosci.* 33, 2017–2027. doi: 10.1111/j.1460-9568.2011.07701.x

Najmi, A., Nazari, S., Safarighouzhdi, F., MacIntyre, C. R., Miller, E. J., and Rashidi, T. H. (2021). Facemask and social distancing, pillars of opening up economies. *PLoS One* 16:e0249677. doi: 10.1371/journal.pone.0249677

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Patané, I., Farnè, A., and Frassinetti, F. (2017). Cooperative tool-use reveals peripersonal and interpersonal spaces are dissociable. *Cognition* 166, 13–22. doi: 10.1016/j.cognition.2017.04.013

Patané, I., Iachini, T., Farnè, A., and Frassinetti, F. (2016). Disentangling action from social space: Tool-use differently shapes the space around us. *PLoS One* 11:e0154247. doi: 10.1371/journal.pone.0154247

Pavani, F., Spence, C., and Driver, J. (2000). Visual capture of touch: Out-of-the-body experiences with rubber gloves. *Psychol. Sci.* 11, 353–359. doi: 10.1111/1467-9280.00270

Proverbio, A. M. (2012). Tool perception suppresses 10–12 Hz μ rhythm of EEG over the somatosensory area. *Biol. Psychol.* 91, 1–7. doi: 10.1016/j.biopsycho.2012.04.003

Quesque, F., Ruggiero, G., Mouta, S., Santos, J., Iachini, T., and Coello, Y. (2017). Keeping you at arm's length: Modifying peripersonal space influences interpersonal distance. *Psychol. Res.* 81, 709–720. doi: 10.1007/s00426-016-0782-1

Ramachandra, V., and Longacre, H. (2022). Unmasking the psychology of recognizing emotions of people wearing masks: The role of empathizing, systemizing, and autistic traits. *Pers. Individ. Differ.* 185:111249. doi: 10.1016/j.paid.2021.111249

Rizzolatti, G., Scandolara, C., Matelli, M., and Gentilucci, M. (1981). Afferent properties of periarcuate neurons in macaque monkeys, II. Visual responses. *Behav. Brain Res.* 2, 147–163. doi: 10.1016/0166-4328(81)90053-X

Schaller, M. (2011). The behavioural immune system and the psychology of human sociality. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 366, 3418–3426. doi: 10.1098/rstb.2011.0029

Schönweitz, F., Eichinger, J., Kuiper, J. M., Ongolly, F., Spahl, W., Prainsack, B., et al. (2022). The social meanings of artifacts: Face masks in the COVID-19 pandemic. *Front. Public Health* 10:789. doi: 10.3389/fpubh.2022.829904

Serino, A., Noel, J. P., Galli, G., Canzoneri, E., Marmaroli, P., Lissek, H., et al. (2015). Body part-centered and full body-centered peripersonal space representations. *Sci. Rep.* 5:18603. doi: 10.1038/srep18603

Sommer, R. (1959). Studies in personal space. *Sociometry* 22, 247–260. doi: 10.2307/2785668

Sorokowska, A., Sorokowski, P., Hilpert, P., Cantarero, K., Frackowiak, T., Ahmadi, K., et al. (2017). Preferred interpersonal distances: A global comparison. *J. Cross Cult. Psychol.* 48, 577–592. doi: 10.1177/0022022117698039

Thiebaut, G., Méot, A., Witt, A., Prokop, P., and Bonin, P. (2021). "Touch Me If You Can!": Individual differences in disease avoidance and social touch. *Evol. Psychol.* 19:14747049211056159. doi: 10.1177/14747049211056159

Twele, A. C., Thierry, S. M., and Mondloch, C. J. (2022). Face masks have a limited influence on first impressions: Evidence from three experiments. *Perception* 51, 417–434. doi: 10.1177/03010066221091729

Vieira, J. B., Pierzchajlo, S. R., and Mitchell, D. G. (2020). Neural correlates of social and non-social personal space intrusions: Role of defensive and peripersonal space systems in interpersonal distance regulation. *Soc. Neurosci.* 15, 36–51. doi: 10.1080/17470919.2019.1626763

Wamain, Y., Gabrielli, F., and Coello, Y. (2016). EEG μ rhythm in virtual reality reveals that motor coding of visual objects in peripersonal space is task dependent. *Cortex* 74, 20–30. doi: 10.1016/j.cortex.2015.10.006

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Facial mask disturbs ocular exploration but not pupil reactivity

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Introduction: The COVID-19 pandemic has imposed to wear a face mask that may have negative consequences for social interactions despite its health benefits. A lot of recent studies focused on emotion recognition of masked faces, as the mouth is, with the eyes, essential to convey emotional content. However, none have studied neurobehavioral and neurophysiological markers of masked faces perception, such as ocular exploration and pupil reactivity. The purpose of this eye tracking study was to quantify how wearing a facial accessory, and in particular a face mask, affected the ocular and pupillary response to a face, emotional or not.

Methods: We used videos of actors wearing a facial accessory to characterize the visual exploration and pupillary response in several occlusion (no accessory, sunglasses, scarf, and mask) and emotional conditions (neutral, happy, and sad) in a population of 44 adults.

Results: We showed that ocular exploration differed for face covered with an accessory, and in particular a mask, compared to the classical visual scanning pattern of a non-covered face. The covered areas of the face were less explored. Pupil reactivity seemed only slightly affected by the mask, while its sensitivity to emotions was observed even in the presence of a facial accessory.

Discussion: These results suggest a mixed impact of the mask on attentional capture and physiological adjustment, which does not seem to be reconcilable with its strong effect on behavioral emotional recognition previously described.

KEYWORDS
eye tracking (ET), pupil, face, emotion, mask, accessory, occlusion

Introduction

Humans, from an early age, show a visual preference for the face (Turati et al., 2005). It is the most informative visual stimulus for social perception, allowing to determine the identity, the gender, the age as well as the emotional state of a person (Bruce and Young, 1986). Facial emotion recognition is an essential skill for living in a social world (Frith, 2009). Indeed, the ability to understand the emotions of others is crucial for good interpersonal relationships. Moreover, an incorrect emotion or identity recognition can interfere with normal social functioning and increase social anxiety (Davis et al., 2011).

Adults can be considered experts in facial processing (Carey, 1992). When a neurotypical person spontaneously observes a face, gaze travels over the eyes, mouth, and nose, thus forming a triangular exploration pattern (Vatikiotis-Bateson et al., 1998), with slight differences depending on gender (Coutrot et al., 2016), cultural context (Blais et al., 2008; Miellet et al., 2013), or individual recognition performance and cognitive abilities (Hsiao et al., 2022). These facial features, the eyes, the nose, and the mouth, have been shown to convey crucial information for face recognition (Keil, 2009), but also emotion recognition (Bassili, 1979), and are explored differently as a function of the emotional content of the face (Hernandez et al., 2009). To evaluate the importance of different facial areas on emotion recognition, studies have either displayed only face parts, blurred or filtered facial features, or displayed parts sequentially (Blais et al., 2012; Bombari et al., 2013; Meaux and Vuilleumier, 2016; Wegrzyn et al., 2017). If the eyes are crucial, these studies also revealed the importance of the mouth in emotion recognition (Blais et al., 2012), in particular for sadness (Bombari et al., 2013), or happiness (Wegrzyn et al., 2017). Other studies have focused on the ocular exploration of emotional faces, combined or not with a recognition task, and have shown that overall fixation time on the eye region is larger for fearful, angry and surprised faces while the mouth is more looked at for happy faces (Hernandez et al., 2009; Guo, 2012; Schurgin et al., 2014). Interestingly, a study combining eye-tracking with an emotional or identity comparison task showed that the lower part of the face is more explored when making an emotional judgment while the reverse was true for identity judgment (Malcolm et al., 2008).

Facial features are essential for face perception; however, face processing is not an analytic process based on isolated features. Indeed many studies have converged in showing that expert facial processing is holistic (Maurer et al., 2002), with the first-order (eyes above nose, and nose above mouth) and second-order (distance between features) relationships between facial features making the face an indivisible and coherent whole. This holistic facial processing therefore requires access to the entire face and raises the question about the effects of partial occlusion on facial exploration or emotion recognition. Many studies conclude that facial expression recognition is hindered when parts of the face are covered (Bassili, 1979; Roberson et al., 2012). Indeed, whether partial occlusion is due to glasses (Roberson et al., 2012) or a scarf (Kret and de Gelder, 2012), it represents an obstacle to reading different facial expression. Studies comparing the occlusion of the eyes and mouth regions showed that the identification of happy expressions is more disturbed by the occlusion of the mouth than the eyes, while for other emotions the results are not so clear. Kotsia et al. (2008) found anger was more disrupted by mouth occlusion and disgust by eye occlusion. Schurgin et al. (2014) reported the opposite trend. The addition of accessories or the occlusion with sunglasses, also has a negative impact on the recognition of unfamiliar faces (Graham and Ritchie, 2019). Nevertheless, accuracy is well above chance level, suggesting that the occlusion of an area does not abolish facial recognition capabilities.

As a result of the COVID-19 health crisis, a large part of the world population has been wearing a facial mask, and concerns about a negative impact of wearing a mask on social interactions have emerged (Saunders et al., 2021). Masks can easily disrupt our ability to reliably recognize or express emotions and information necessary for good communication during our daily social interactions (Marler and Ditton, 2021). Moreover, the surgical mask can have a negative psychological impact and induce stress and gloom in observers (Saint and Moscovitch, 2021; Saunders et al., 2021). Many studies on the effect of observing a masked face have recently been carried out. As in previous occlusion studies, facial expression recognition seems affected. Noyes et al. (2021) contrasted faces wearing a mask or sunglasses with bare faces on several emotions recognition and showed a decrease in emotion recognition accuracy when the mouth was masked. Carbon (2020) and Freud et al. (2020) showed that emotional identification was strongly disturbed by the presence of a mask, in particular for sadness. However, many of these studies used digitally added masks to existing emotional face photos, lacking naturalness. Moreover, few studies on masked face perception used dynamic stimuli (videos), although this realistic aspect plays a key role in the discrimination of different emotions (Blais et al., 2012). Dynamism is indeed considered as an important component of naturalistic stimuli (Richoz et al., 2018) and impact physiological arousal (Aguillon-Hernandez et al., 2020). To take this aspect into account, we created a set of videos of actors displaying different emotions (neutral, happiness, and sadness), filmed either bare face or while really wearing several facial accessories (sunglasses, scarf, and surgical mask). With these new controlled ecological videos, we demonstrated that real-worn masks impacted emotion recognition (Aguillon-Hernandez et al., 2022). We found an effect of mask on visual emotion recognition with a loss of accuracy of 17% for happiness and 25% for sadness. Importantly, we had no effect of sunglasses and an effect of scarf only on sadness recognition (Aguillon-Hernandez et al., 2022).

While occlusion has a clear effect on emotion recognition, it is not clear whether this is related to the reduced amount of available information (thus thwarting ocular exploration), a reduced attentional capture, a disturbed holistic processing, or an altered physiological arousal. Several of these processes can be inferred from eye-tracking studies. Indeed, ocular exploration of a scene is guided both by low-level, bottom-up information (for example, movement, color), and several top-down factors like expectation, internal representations, and social information for example (Flechsenhar and Gamer, 2017). This information would be combined in a saliency map or priority map guiding attention and eye movements (e.g., Treue, 2003). To our knowledge, only one study looked at the modulation of visual exploration patterns by surgical masks (Hsiao et al., 2022) and reported eye-focused exploration patterns in masked faces. These results need to be extended to emotional and dynamic faces, and contrasted with other facial accessories.

Recorded simultaneously with ocular exploration, pupil diameter variation is another interesting marker of facial processing (Martineau et al., 2011; Aguillon-Hernandez et al., 2020). Pupillary dilation can be used as a physiological marker of social or affective arousal in response to the presentation of faces, emotional or not (Ekman, 1992). Indeed, evoked pupil responses are strongly correlated with the activity of the noradrenergic nuclei of the locus coeruleus (Joshi et al., 2016), linked to the attentional engagement or arousal of a subject (Sara and Bouret, 2012). However, pupil dilation exhibit slow dynamics and cannot easily distinguish successive processing or cognitive steps, thus integrating many inputs like sensory saliency, cognitive representations or emotion processing (e.g., Joshi and Gold, 2020). Previous work has shown that faces with emotional valence yield greater pupil dilation (Bradley et al., 2008), exacerbated for negative valence emotions (Yrttiaho et al., 2017; Aguillon-Hernandez et al., 2020). A study by Aguillon-Hernandez et al. (2020) highlighted physiological adjustment to ecological social stimuli, with larger pupil dilation for social (neutral and emotional faces) compared to non-social stimuli and for dynamic stimuli (videos of faces) compared to static stimuli (photos of faces).

The goal of this study was to quantify how wearing a facial accessory, and in particular a COVID-19 mask, affected ocular and pupillary responses to the observation of a face, emotional or not. We used videos previously created and behaviorally evaluated (Aguillon-Hernandez et al., 2022), featuring four facial conditions (no accessory, sunglasses, tube scarf, and COVID-19 mask) and three emotional conditions (neutrality, happiness, and sadness). The comparison of the mask and scarf conditions aimed to dissociate the effect of the occlusion of the lower part of the face from a possible negative psychological impact specific to the surgical mask (Saunders et al., 2021). In order to measure spontaneous responses, as close as possible from a real ecological interaction, we did not ask any judgment about emotion recognition. As the accessories masked the main regions of interest of the face (eyes or mouth), we expected ocular exploration to be altered in the presence of an accessory, maybe redirecting gaze toward the visible part of the face (as observed by Hsiao et al., 2022). For the pupillary response, we expected a greater dilation for emotional faces compared to neutral faces as already described (Aguillon-Hernandez et al., 2020). This response could be reduced in the presence of an accessory, in particular masking the mouth, as emotions are less recognized in this condition (Aguillon-Hernandez et al., 2022).

Materials and methods

Participants

We recruited 44 participants (22 females), aged 18–35 (mean = 23.23 ± std 3.26 year). This age range was chosen to minimize variations in basal pupil diameter (Fairhall et al., 2006). Exclusion criteria were abnormal or uncorrected vision, personal history of psychiatric or neurological disorders, and personal history of learning difficulties, difficulties in learning to walk or speak. Written informed consent was obtained prior to the experiment. The study was approved by an Ethics Committee (CPP, protocol PROSCEA 2017-A00756-47) and conformed with the Declaration of Helsinki (World Medical Association, 2013).

Stimuli and protocol

The stimulus set was evaluated in a previous study (Aguillon-Hernandez et al., 2022) focusing on explicit behavioral emotion recognition. It was composed of videos of faces, expressing different realist emotions and wearing or not a facial accessory. The accessory covered either the upper part of the face (sunglasses) or the lower part of the face (mask and tube scarf, sometimes called neck gaiter). A total of 48 videos were tested: 4 actors (2 males) × 3 emotions (neutrality/happiness/sadness) × 4 facial occlusion conditions (no accessory/sunglasses/scarf/mask) (**Figure 1A**). Each video started with an actor in a neutral state that either stayed neutral or performed an emotion before returning to neutral. The emotional content of the videos without accessory was validated both objectively (FaceReader®, FR6, Noldus, Wageningen, The Netherlands) and subjectively (Aguillon-Hernandez et al., 2022). All videos were processed to last 2 s, to frame each face identically, and to be matched in colorimetry. Global luminosity of the stimuli and the room were controlled and kept constant (25 Lux) for each participant. The stimuli were presented in the center of a 27-inch monitor with a resolution of 1,920 × 1,080 px. In-between each video, an inter-trial image composed of a uniform background and a central black cross (located at the level of the upper nose, **Figure 1B**) was presented, matched in colorimetry and luminosity with the videos.

The set of 48 videos was presented three times to each participant. For each block, the order of presentation was randomized. Inter-trial stimulus interval was between 2 and 4 s (**Figure 1B**). No instructions were given to the participants except to look at the screen and remain silent.

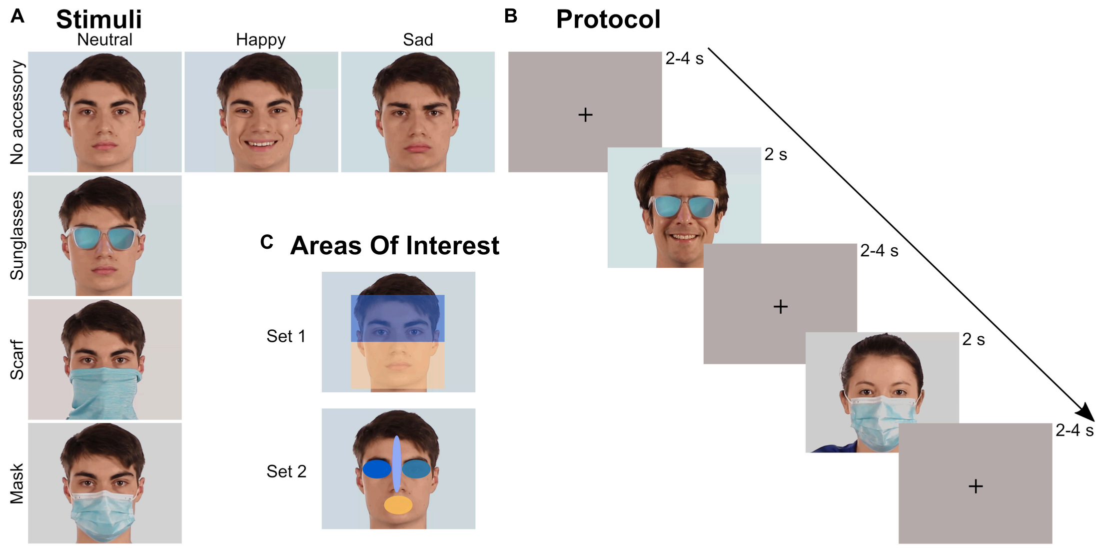

FIGURE 1
Stimuli and protocol. **(A)** Stimuli: videos of four actors (2 males) with four occlusion and three emotion conditions were tested. **(B)** Protocol: each video lasted 2 s and was preceded by a 2–4 s inter-trial uniform image with a black cross. The 48 videos were randomly presented during a block. Three blocks were recorded by participant. **(C)** Areas of Interest (AOI): two sets of AOIs were created to analyze the ocular exploration. Within each set, the different AOIs covered the same area.

Data acquisition and processing

Data were acquired with a Tobii® Pro Fusion eye tracker (Tobii, Stockholm, Sweden; sampling rate of 250 Hz), with an accuracy of 0.3° and a precision of 0.04° in optimal conditions. The protocol was run with Tobii® Pro Lab. Each participant was installed in a comfortable armchair in front of the monitor at a distance of about 70 cm (distance calculated by the eye tracker: 57.3–78.2 cm). Before each block of videos, a nine-point calibration procedure was performed using animated circles to attract the gaze.

The ocular exploration of the videos was analyzed through several parameters depending on Areas of Interest (AOIs). We created several AOIs: first the whole screen, to check that all the videos were equally explored, then two different sets of AOIs (Figure 1C). Within each set, all AOIs had the same surface (rectangles in Set 1: 320,000 px; ellipses in Set 2: 30,278 px). Set 1 divided the face into two large parts: the upper part (containing the eyes), and the lower part (containing the whole surgical mask). Set 2 consisted of four elliptical AOIs located on the mouth, the right eye, the left eye, and the space between the eyebrows including the tip of the nose. We mainly analyzed the time spent (in s) within those AOIs, relatively to the total time spent on the screen, as computed by Tobii Pro Lab (every valid eye tracking sample). We also analyzed the latency of the first entry (in ms) in each AOI of Set 2.

For pupil analysis, we extracted raw data from Tobii and processed the signal using in-house MATLAB scripts. Some data loss was observed for some participants. Except in one subject, data loss always lasted less than the duration of a blink (200–300 ms) and was interpolated to its nearest values. For the subject with longer data loss, trials ($n = 2$) with lost data were removed. Blinks and signal artifacts were identified thanks to a velocity threshold and pupil diameter values were replaced by the median values of a pre- and post-blink 120 ms interval. Then, we applied a median filter to remove signal artifacts and smooth the signal. Residual blinks were visually identified and manually interpolated. For each trial (starting at video onset), a baseline pupil size was calculated by taking the median value of the pupil diameter recorded over the last 200 ms before the video onset. This baseline value was subtracted from the pupillary diameter recorded during the 4 s after the start of the video presentation (2 s of video and 2 s of inter-trial). For each participant, a mean time course was calculated for each of the 12 categories (3 emotions × 4 accessories). We extracted several parameters from these time courses: the dilation peak amplitude (maximum pupillary diameter between 1.1 and 3.4 s, in mm) and its latency (in ms).

Statistical analyses

Statistical analyses were carried out using the software Statistica13®. For all parameters, normality of the distribution and homogeneity of variance were verified with the Kolmogorov–Smirnov and Levene tests.

The influence of the accessory (×4: no accessory, sunglasses, scarf, and mask) on the different parameters according to the emotion (×3: neutral, happy, and sad) and the AOIs for ocular exploration (×2 for Set 1 and ×4 for Set 2), was evaluated with a repeated measure ANOVA within the General Linear Model (GLM) Framework, corrected by Greenhouse–Geisser and completed by *post-hoc* corrected planned multiple comparisons. Pupil time courses were also analyzed with a GLM, adding the effect of time (×8 time points: one mean value for each 500 ms time interval), with Bonferroni multiple comparisons. *P*-corrected values and effect size (η^2) are provided for each significant effect.

Without any *a priori* hypothesis about the statistical size effect expected, we performed *a posteriori* G*Power® 3.1 sensitivity analysis. We evaluated we could expect a small effect size of $f = 0.15$ ($\eta^2 = 0.022$) according to the size of our population ($n = 44$), an error probability of 0.05 and a power of 0.95.

Results

Ocular exploration of faces

We analyzed how the participants explored the videos of the faces, depending on the accessory worn (or not) and the emotion displayed. Qualitatively, we observed the classical ocular pattern when exploring a bare face (i.e., mainly exploration of the eyes and the mouth; see an example in **Figure 2**). This pattern was modified by the presence of an accessory. To quantify these observations, we analyzed the effect of three factors: accessory, emotion and AOI on the time spent within several AOIs.

With AOIs of Set 1 (**Figures 1C**, **3**), we observed a main effect of the accessory [$F_{(3,132)} = 3.96$; $p < 0.01$, $\eta^2 = 0.08$], with a time spent in AOIs in the scarf and mask conditions significantly lower than in the sunglasses condition ($p < 0.05$ for both), and a main effect of the AOI [$F_{(1,44)} = 268.16$; $p < 0.0001$, $\eta^2 = 0.86$], with a greater time spent in the upper AOI. Three interactions were also significant ("Accessory × AOI," "Emotion × AOI," and "Accessory × Emotion × AOI").

First, we obtained a significant "Accessory × AOI" interaction [$F_{(3,132)} = 100.47$; $p < 0.001$, $\eta^2 = 0.69$; **Figure 3B**]. Masking the lower part of the face, with a mask or a scarf, significantly increased the time spent in the upper AOI compared to the sunglasses and no accessory conditions ($p < 0.001$ for each comparison) and decreased the time spent in the lower AOI (scarf < sunglasses and no accessory, mask < sunglasses and no accessory, $p < 0.001$ for each comparison). Finally, the sunglasses biased the exploration toward the lower part of the face compared to the no accessory condition ($p < 0.001$ for each comparison).

Secondly, we obtained a significant "Emotion × AOI" interaction [$F_{(2,88)} = 81.684$; $p < 0.001$, $\eta^2 = 0.65$; **Figure 3C**]: in the happy condition the exploration was biased toward the lower part of the face compared to neutrality and sadness ($p < 0.001$ for each comparison and each AOI).

Finally, we observed a significant "Accessory × Emotion × AOI" interaction [$F_{(6,264)} = 10.171$; $p < 0.001$, $\eta^2 = 0.19$; **Figure 3A**]. In the happy condition, the time spent in the lower AOI was higher when wearing sunglasses and decreased depending on the accessory (sunglasses > no accessory > scarf > mask, $p < 0.001$ for all comparisons); the reverse pattern was observed for the upper AOI (sunglasses < no accessory < scarf < mask, $p < 0.001$ for all comparisons). For both the sad and neutral conditions (which did not differ), the time spent in the lower AOI was higher when wearing sunglasses than no accessory, and in the no accessory condition compared to both the scarf and mask conditions (which did not differ; sunglasses > no accessory > scarf = mask, $p < 0.001$ for the significant comparisons); the reverse pattern was observed for the upper AOI (sunglasses < no accessory < scarf = mask, $p < 0.001$ for all significant comparisons).

In the Set 2 of AOIs (**Figure 1C**), four regions were analyzed (left and right eyes, mouth and space between the eyes, **Figure 4**). We observed a main effect of the accessory [$F_{(3,132)} = 11.943$; $p < 0.001$, $\eta^2 = 0.21$], with a time spent in AOIs significantly lower when wearing sunglasses compared to the other accessory conditions ($p < 0.001$ for all comparisons). We also observed a main effect of the AOI [$F_{(1,132)} = 25.224$; $p < 0.001$, $\eta^2 = 0.36$], with a higher time spent within the center AOI compared to the three other AOIs ($p < 0.001$ for all comparisons), and a lower time spent in the mouth AOI compared to the three other AOIs ($p < 0.001$ for all comparisons). No significant difference was observed between the time spent on the left or right eye. Four interactions

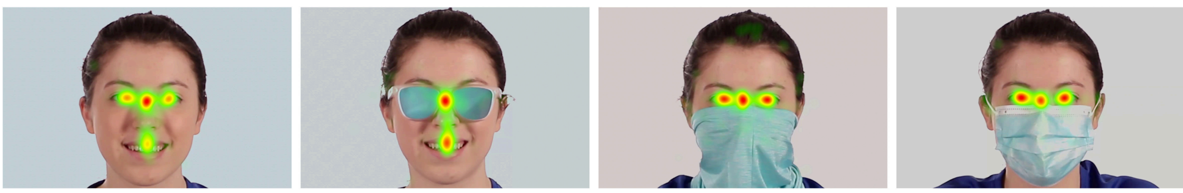

FIGURE 2
Example of heat maps for the exploration of a happy face. The mean time spent for all participants is represented by a color gradient from green (low time spent) to red (high time spent).

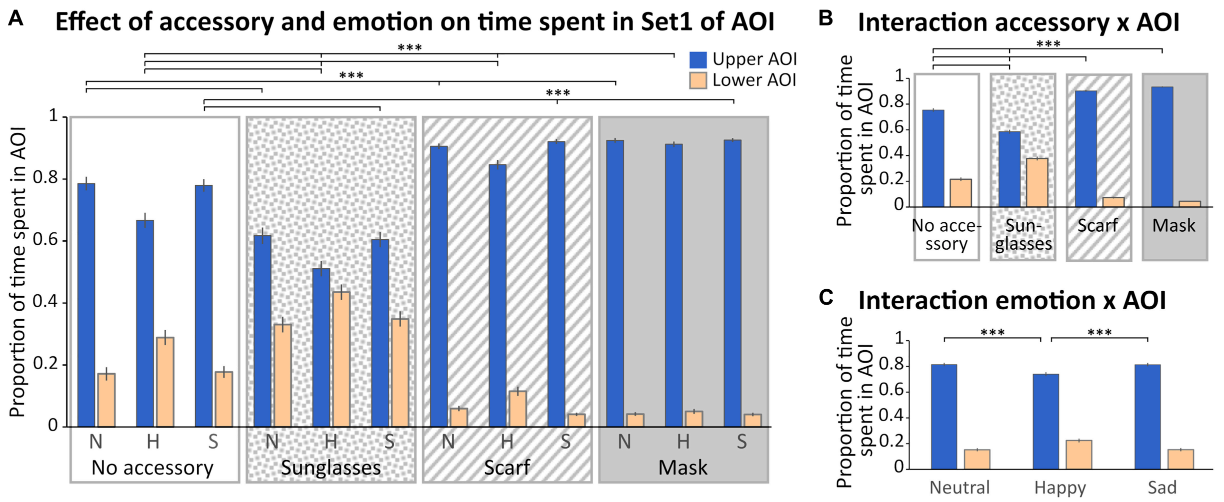

FIGURE 3
Analysis of the time spent in Set 1 of AOI. **(A)** Mean (± standard error) of the proportion of time spent (relative to the time spent on the screen) in the Areas of Interest (AOIs) (upper AOI: blue, left columns; lower AOI: yellow, right columns) according to accessory (no accessory: white background; sunglasses: dotted background; scarf: hatched background; mask: gray background) and emotion (neutral: N, happy: H, and sad: S). **(B)** Mean (± standard error) of the proportion of time spent in the AOIs illustrating the accessory × AOI interaction. **(C)** Mean (± standard error) of the proportion of time spent in the AOIs illustrating the emotion × AOI interaction. For sake of clarity, only the significant comparisons for the upper AOI are illustrated. The pattern is identical for the lower AOI. ***$p < 0.001$.

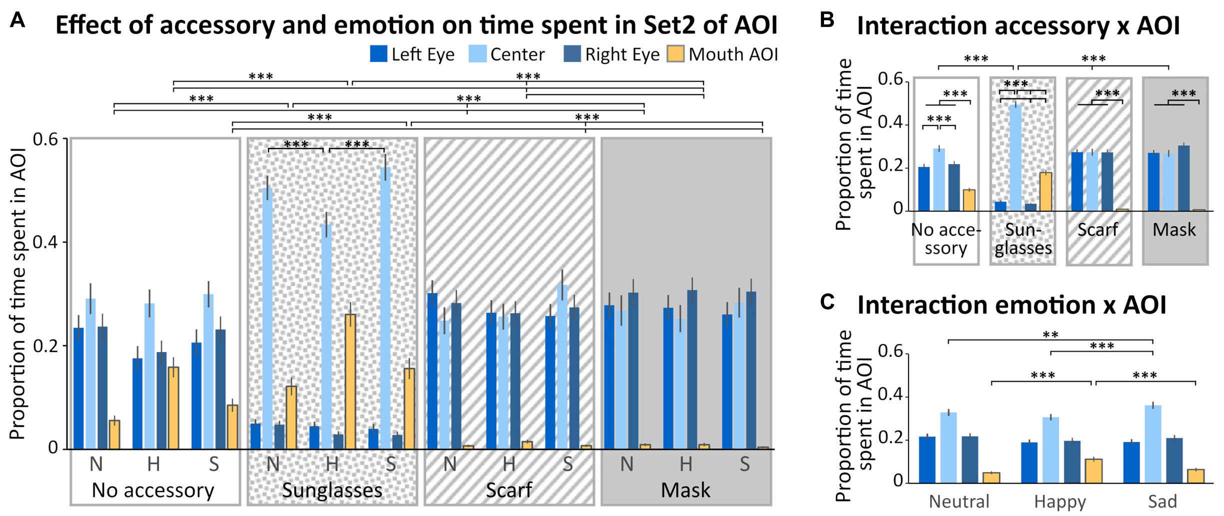

FIGURE 4
Analysis of the time spent in Set 2 of AOI. **(A)** Mean (± standard error) of the proportion of time spent (relative to the time spent on the screen) in the Areas of Interest (AOIs) (left eye: medium blue, first columns; center: light blue, second columns; right eye: dark blue, third columns; mouth: yellow, last columns) according to accessory (no accessory: white background; sunglasses: dotted background; scarf: hatched background; mask: gray background) and emotion (neutral: N, happy: H, and sad: S). For sake of clarity, only the significant comparisons for the mouth AOI are illustrated. The pattern is identical for the left and right eyes AOIs, except for the scarf vs mask comparison (see Results section). We also illustrated the comparisons within the sunglasses condition. **(B)** Mean (± standard error) of the proportion of time spent in the AOIs illustrating the accessory × AOI interaction. **(C)** Mean (± standard error) of the proportion of time spent in the AOIs illustrating the emotion × AOI interaction. **$p < 0.01$; ***$p < 0.001$.

("Accessory × Emotion," "Accessory × AOI," "Emotion × AOI," and "Accessory × Emotion × AOI") were significant.

First, we obtained a significant "Accessory × Emotion" interaction [$F_{(6,264)} = 3.8022$; $p < 0.01$, $\eta^2 = 0.08$]. In the sad and neutral conditions, the time spent in AOIs was lower for the sunglasses than for the three other accessory conditions ($p < 0.01$). When wearing a scarf, the time spent in AOIs was significantly lower in the happy compared to sad condition

($p < 0.01$). When wearing sunglasses, the time spent in AOIs was significantly lower in the neutral compared to happy condition ($p < 0.01$).

Secondly, we obtained a significant "Accessory × AOI" interaction [$F_{(9,396)} = 80.557$; $p = 0.002$, $\eta^2 = 0.65$; **Figure 4B**]. For the mask, scarf and no accessory conditions, the time spent in the mouth AOI was lower than for the three other AOIs ($p < 0.001$ for all comparisons). For the no accessory condition, the time spent in the center AOI was higher than for the three other AOIs ($p < 0.001$ for all comparisons). For the sunglasses condition, the time spent in the center AOI was higher than in the mouth AOI, which was higher than in the two eyes AOIs (center > mouth > left and right eyes, $p < 0.001$ for all comparisons). The center AOI was more fixated in the sunglasses condition than in the other accessory conditions ($p < 0.001$ for all comparisons).

Thirdly, we obtained a significant "Emotion × AOI" interaction [$F_{(6,264)} = 24.690$; $p < 0.001$, $\eta^2 = 0.36$; **Figure 4C**]. Specifically, we observed that the time spent in the center AOI in the sad condition was higher than for happy ($p < 0.001$) or neutral ($p < 0.01$) conditions. Moreover, the time spent in the mouth AOI was higher in the happy than in the sad and neutral conditions ($p < 0.001$ for both comparisons).

Finally, we obtained a significant "Accessory × Emotion × AOI" interaction [$F_{(18,792)} = 9.5766$; $p < 0.001$, $\eta^2 = 0.18$; **Figure 4A**]. In the happy condition, the time spent in the mouth AOI was higher when wearing sunglasses and decreased depending on the accessory (sunglasses > no accessory > scarf > mask, $p < 0.001$ for all comparisons). The reverse pattern was observed for the left and right eye AOIs, except that there was no difference between the scarf and the mask conditions (sunglasses < no accessory < scarf = mask, $p < 0.001$ for the significant comparisons). For both the sad and neutral conditions (which did not differ), the time spent in the mouth AOI was higher when wearing sunglasses than other accessories, and in the no accessory condition compared to both the scarf and mask conditions (which did not differ; sunglasses > no accessory > scarf = mask, $p < 0.001$ for the significant comparisons); the reverse pattern was observed for the left and right eye AOIs (sunglasses < no accessory < scarf = mask, $p < 0.001$ for all significant comparisons). Moreover, when wearing sunglasses, the time spent in the center AOI was lower in the happy compared to sad and neutral conditions ($p < 0.001$ for both comparisons).

To go further in the analysis of the exploration pattern, we also analyzed the latency of the first entry within the four AOIs of Set 2. We hypothesized that the time spent in the center AOI may reflect the fact that the fixation cross present during inter-trial was located within this AOI and, as a consequence, the exploration always started from that location. Indeed, participants' gaze was almost always located within the center AOI at the beginning of the exploration, as the mean latency of the first entry in this AOI was 54 ms. We analyzed the effect of accessory and emotion on the latency of the first entry within the three other AOIs. We observed a main effect of the accessory [$F_{(3,27)} = 12.44$; $p < 0.001$, $\eta^2 = 0.58$], with a latency of the first entry significantly longer when wearing sunglasses compared to the other accessory conditions ($p < 0.001$ for all comparisons; mean latency of the first entry ± Std: sunglasses 1,006 ± 465 ms, no accessory 880 ± 420 ms, mask 833 ± 469 ms, scarf 829 ± 437 ms), i.e., a longer fixation within the center AOI before exploring the face. We also observed a main effect of the AOI [$F_{(2,18} = 11.56$; $p < 0.01$, $\eta^2 = 0.56$], with the left eye AOI being explored first ($p < 0.001$ compared to right eye AOI, $p < 0.05$ compared to the mouth AOI; left eye AOI 785 ± 432 ms, right eye AOI 895 ± 448 ms, mouth AOI 982 ± 458 ms). We obtained a significant "Accessory × AOI" interaction [$F_{(6,54)} = 12.62$; $p < 0.0001$, $\eta^2 = 0.58$], reflecting the fact that masking the lower part of the face (scarf and mask conditions, that did not differ) delayed the exploration of the mouth AOI ($p < 0.05$ for all comparisons; no significant difference between the sunglasses and no accessory conditions) and masking the upper part of the face (sunglasses) delayed the exploration of the eyes ($p < 0.05$ for all comparisons; no significant difference between the scarf, mask and no accessory conditions). However, we found no significant effect of emotion, nor any significant interaction involving emotion. To summarize, accessories not only affected the cumulated time spent in the different AOIs, but also affected the spatial strategy of exploration, with the non-masked regions explored first.

Pupillary reactivity to faces

We analyzed how the pupil diameter varied as a function of the accessory and the emotion displayed in the videos. **Figure 5** shows the mean pupil variation as a function of the accessory (**Figure 5A**) or of the emotion (**Figure 5C**) during 4 s (the first 2 s corresponded to the video presentation, followed by 2 s of inter-trial stimulus). We observed a rapid pupil constriction followed by a pupil dilation and, after the end of the video, a return to baseline. The analysis of the time courses showed that we indeed obtained a main effect of time [$F_{(7,301)} = 106.08$, $p < 0.0001$, $\eta^2 = 0.71$], with the first 500 ms significantly different from all the other 500 ms windows until 3,500 ms ($p < 0.0001$ for all comparisons, except 0–500 ms vs. 3,000–3,500 ms $p < 0.05$). First, we observed a significant "Accessory × Time" interaction [$F_{(21,903)} = 4.40$, $p < 0.001$, $\eta^2 = 0.09$], illustrating early differences in the time courses (**Figure 5A**), with the sunglasses and scarf conditions eliciting earlier dilation than the two other conditions (scarf > no accessory $p < 0.05$ 500–1,500 ms, scarf > mask $p < 0.01$ 1,000–1,500 ms, sunglasse > no accessory $p < 0.01$ 500–1,000 ms, sunglasses > mask $p < 0.05$ 500–1,000 ms). The analysis of the time courses also revealed a main effect of emotion [$F_{(2,86)} = 7.42$, $p < 0.01$, $\eta^2 = 0.15$], with the sad condition significantly different from the neutral condition ($p < 0.001$). A significant "Emotion × Time" interaction [$F_{(14,602)} = 13.51$, $p < 0.0001$, $\eta^2 = 0.24$] revealed that the sad condition produced a larger dilation than the happy condition, itself larger than the neutral condition, in different time windows (**Figure 5C**; sad > happy $p < 0.0001$ for 1,500–2,500 ms; sad > neutral $p < 0.0001$ for 1,500–4,000 ms; happy > neutral $p < 0.0001$ for 2,000–4,000 ms).

We were interested in analyzing pupil dilation, *a priori* reflecting the cognitive and emotional content of the video. We thus extracted the amplitude (peak dilation) and latency (peak latency) of the peak pupil dilation. We analyzed the effect of the accessory and the emotion on peak dilation. There was no main effect of the accessory, but a main effect of the emotion [$F_{(2,86)} = 21.71$; $p < 0.001$, $\eta^2 = 0.33$]. Indeed, as observed on the time courses (**Figure 5C**), peak dilation was significantly higher for sadness compared to happiness ($p < 0.01$) and neutrality ($p < 0.001$). We also observed a significant "Accessory × Emotion" interaction [$F_{(6,258)} = 2.48$; $p < 0.024$, $\eta^2 = 0.05$]. For both the scarf and sunglasses conditions, peak dilation was larger in the sad compared to the neutral condition ($p < 0.001$ for both comparisons), while the comparison with the happy condition was significant only when wearing sunglasses ($p < 0.01$). However, there was no significant difference in the peak dilation induced by sadness for the different accessory conditions. We also observed a small significant effect of the accessory on peak latency [$F_{(3,129)} = 3.048$; $p < 0.031$, $\eta^2 = 0.07$; **Figure 5B**], with a longer latency for the mask compared to the scarf conditions ($p < 0.05$), while there was no effect of emotion nor an "Accessory × Emotion" interaction on pupil peak latency. We tested the correlation between peak latency and peak dilation, these two parameters were not correlated.

Discussion

In this study, we examined the influence of facial accessories, and in particular the face mask, on the ocular behavior and pupillary reactivity in response to emotional and non-emotional faces. We observed a significant impact of both the accessories and the emotional content on the ocular exploration of the face, but mainly an effect of emotion on pupil dilation.

The ocular exploration of a face wearing an accessory was modified compared to the classical exploration pattern (Vatikiotis-Bateson et al., 1998; Blais et al., 2008; Miellet et al., 2013; Coutrot et al., 2016) found in the no accessory condition. When we considered the time spent on the whole face (Set 1 of AOIs), the upper part of the face was always the most visited but the time spent in this AOI was influenced by the accessory. As expected, covering the lower part of the face (by a scarf or a mask) decreased the time spent on the lower part and increased the time spent on the upper part of the face; conversely, covering the upper part of the face (with sunglasses) increased the time spent in the lower part of the face. Both are consistent with Hsiao et al. (2022) who suggested that ocular movements during a face recognition task were guided by the visual information available, mainly the eyes region when the face is masked. Reduced low-level visual input would indeed decrease the saliency of the masked parts of the face, thus capturing less attention and gaze. A more precise spatial analysis (Set 2 of AOIs) revealed interesting exploration patterns in the upper and lower parts of the face. Indeed, the time spent on the upper part of the face was not focused only on the eyes: there was a bias toward the space between the eyes, more pronounced when observing a face wearing sunglasses and absent when the lower part of the face was covered. So, while the upper part of the face was still more explored when observing somebody wearing sunglasses, the eyes region was not explored. The exploration of the space between the two eyes was already described by Schurgin et al. (2014) but should be interpreted with caution. Indeed, this bias could be explained by the location of the fixation cross during the inter-trial: in our study as in Schurgin's, before the presentation of the face, a cross was displayed allowing for the ocular exploration of the face always to start from the same location. As a result, all participants spent time at this location at least at the start of each trial, as confirmed by the analysis of the latency of the first entry in the center AOI. In the scarf and mask conditions, the inter-eyes region was less explored than in the no accessory condition, potentially reflecting a less dispersed exploration. The time spent on the lower part of the face was focused on the mouth when it was visible, but, as could be expected, was more dispersed when the mouth was covered. In the sunglasses condition, with no visible eyes to explore, the analysis of the latency of the first entry in the other AOIs suggested a longer disengagement from this location. We had hypothesized that, the eyes being considered as more salient than the mouth (Pesciarelli et al., 2016), when they are masked by sunglasses the gaze would be attracted toward the next most salient part of the face, i.e., the mouth. While indeed the mouth was overall more explored in this condition, the dynamics of the exploration (as indexed by the latency of the first entry in the AOI) revealed that the mouth AOI was not visited more quickly. The longer disengagement from the center location at the beginning of the exploration in the sunglasses condition could thus reveal either a low saliency of the unmasked parts of the face, or more probably a perturbation of the prototypical exploration strategy starting on the eyes. Guo (2007) has proposed that, in the context of face exploration, non-human primates always explore the eyes' location first, even when the content of that region was modified. Our data do not allow to test completely this hypothesis as the exploration always starts from the location between the eyes, which could be considered as within the overall eye region. On the other hand, a recent model suggested that low-level saliency influenced only the first saccade, all subsequent saccades being better explained by top-down factors (Schütt et al., 2019). Our results suggest

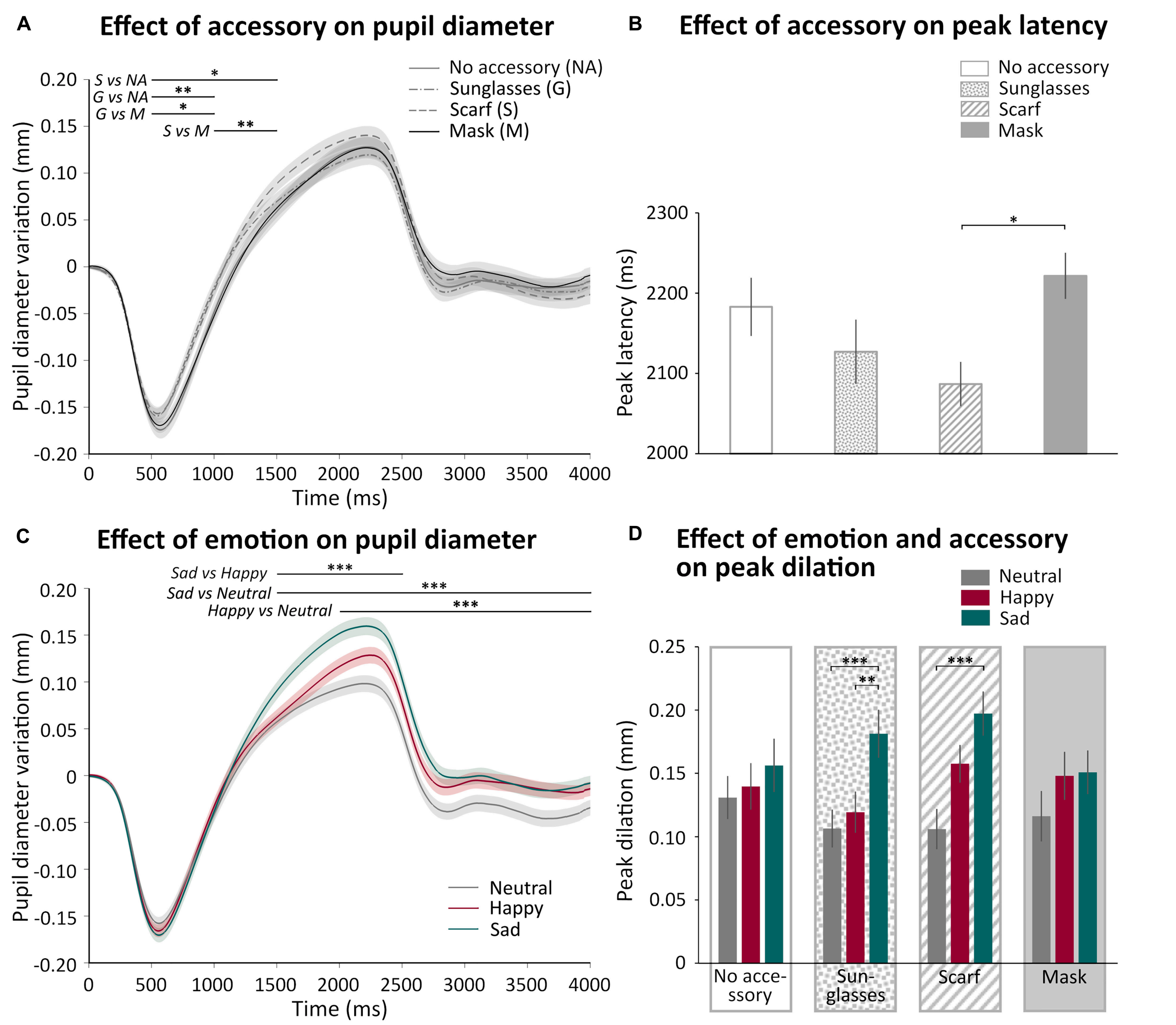

FIGURE 5
Effect of accessory and emotion on pupil variations. **(A)** Mean (± standard error) pupil variation (mm) of all participant during 4 s according to accessory (no accessory NA: solid gray, sunglasses G: dash point gray, scarf S: dashed gray, and mask M: solid black). **(B)** Mean (± standard error) peak latency (ms) of all participant according to accessory (no accessory: white; sunglasses: dotted; scarf: hatched; mask: gray). **(C)** Mean (± standard error) pupil variation (mm) of all participant during 4 s according to emotion (neutral: gray; happy: burgundy; sad: green). **(D)** Mean (± standard error) peak dilation (mm) of all participant according to accessory (no accessory: white, first panel; sunglasses: dotted, second panel; scarf: hatched, third panel; mask: gray, last panel) and emotion (neutral: gray, left columns; happy: burgundy, middle columns; sad: green, right columns). $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

that the dynamic of this first saccade can still be influenced by internal factors.

To our knowledge, visual exploration of emotional faces wearing accessories has not yet been studied. Interaction between the accessories and the emotional content mainly reflected an effect of accessory on happy faces: the lower part of the face and the mouth were more explored when the faces were smiling (Guo, 2012; Schurgin et al., 2014), with a larger effect when the eyes were covered and a smaller effect when the mouth was covered. While we interpret these results as an impact of the emotional content of the stimulations, we cannot rule out that the time spent on the mouth in the happy condition may be explained at least partly by low-level local movement information attracting the gaze. This effect was not found on the latency of the first entry in the AOIs, possibly because of the dynamic nature of the stimuli (the smile was not visible at the beginning of the video). The only effect specific to the mask was that the time spent on the mouth in the happy condition was lower compared to that of the scarf condition, and did not differ from the other emotional conditions. The difference for the scarf and the mask in the happy condition could be linked to the specific decrease in happiness recognition in our previous behavioral study (Aguillon-Hernandez et al., 2022) for faces wearing a mask. It is possible that the tube scarf we used for the videos still allowed access to some movement information, preserving happiness recognition and the exploration bias toward the mouth (when compared to the other emotions). Note that the results differed between ocular exploration and behavioral responses using the same stimuli (Aguillon-Hernandez et al., 2022). Indeed, we observed a decreased performance for sadness recognition in the mask and scarf conditions, while the visual strategy did not seem to differ between the neutral and sad faces in the present study. The exploration strategies observed made the best of the available information on the face. It is not clear if the results would have been different if participants had explicitly been asked to judge the emotional content of the videos while the ocular exploration was recorded. The exploration pattern obtained for non-covered faces was similar to the pattern obtained in studies combining visual exploration measurement and emotional recognition task (Guo, 2012; Schurgin et al., 2014). Moreover, in his study, Guo reduced the intensity of emotions on the faces, inducing a decreased recognition performance, without exploration pattern modifications. Note however, that a slight change in ocular strategy cannot be excluded when given an explicit recognition instruction (Malcolm et al., 2008). Task instructions participate to behavioral relevance, i.e., to top-down factors influencing gaze exploration (Treue, 2003), even if it has been proposed that social information takes priority irrespective of task demands (Flechsenhar and Gamer, 2017).

While emotional recognition performance (Aguillon-Hernandez et al., 2022) and ocular exploration (this study) are affected by facial accessories, their effect is minor on physiological arousal reflected by pupil dilation. We observed a very large and robust effect of the emotional content. The emotions we studied (sadness, happiness, and neutrality) influenced the peak pupil dilation, with a greater dilation for sadness. This result is in agreement with the consensus that pupil diameter increases when emotional stimuli are observed (Bradley et al., 2008), reflecting a physiological arousal probably related to greater empathic engagement (Frith, 2009). For example, Bradley et al. (2008) showed an increase in pupil diameter when adult participants observed happy or sad images compared to neutral images (not specifically faces). More recently, Aguillon-Hernandez et al. (2020) showed that the pupils of neurotypical children were sensitive to the emotional content of the face, and especially sadness, only when the stimuli were dynamic, as in the present study. Finally, Partala et al. (2000) reported an increase in pupillary dilation when listening to emotionally valenced sounds, compared to neutral sounds, showing the influence of emotion on pupil even when the stimulus is not visual. We also observed an interaction between accessory and emotion on the peak pupil dilation, with a greater pupil dilation for sadness mainly present in the scarf and sunglasses conditions. Sadness did not seem to evoke a larger dilation than happiness when observing a masked face (even if not significantly different from sadness in the other accessory conditions). This result could be linked to the decreased performance in sadness recognition in presence of the mask (Aguillon-Hernandez et al., 2022), or to a psychological effect of the mask (Marler and Ditton, 2021; Saunders et al., 2021) that could hinder the processing of the emotional content of the face. The differences of pupil dilation in response to sadness might also reflect a difference in exposure between the accessories, with mask having become usual in our everyday life. A combination of unfamiliarity and negative emotion could possibly evoke a larger activation of the amygdala (Straube et al., 2011; Mattavelli et al., 2014), a probable source of pupil dilation modulation (see below). Further studies should explore frequency of exposure, and its link to explicit emotional recognition, to go further in the interpretation of these results.

The presence of an accessory only produced small effects on pupillary parameters, which need to be confirmed with a larger population, with a latency of the peak pupil dilation slightly longer in the mask than in the scarf condition. This latency was not correlated with the amplitude of peak dilation itself. Such a small latency effect is difficult to interpret considering the slow dynamics and integrative nature of pupil dilation. As there is no low-level difference between the mask and scarf conditions, this effect could possibly reflect a delay in the processing of masked faces due to a cognitive bias (Marler and Ditton, 2021; Saunders et al., 2021).

The robust main effect of emotion on pupil dilation, regardless of the presence and nature of the accessory, and with short video presentations of 2 s, suggests that, even if emotion recognition is hindered (Aguillon-Hernandez et al., 2022), an implicit emotional processing is still preserved. While facial emotion processing involve both cortical and subcortical regions (e.g., Williams et al., 2006), subliminal presentation or unseen stimuli would mainly activate the subcortical regions (Morris et al., 1999; Williams et al., 2006). This implicit processing would involve a fast subcortical loop (Johnson, 2005), including amygdala, participating in face detection and modulated by emotional processing. This subcortical loop could directly modulate pupil diameter via projections from the amygdala onto the reticular formation, probably in the same way subliminal fear can induce skin conductance responses (Williams et al., 2006). We propose that this fast subcortical loop implicitly processes emotional cues present on the face even when an accessory is worn, but that this emotional signal would not be sufficient for a completely preserved explicit recognition. Explicit recognition, relying on a large cortical and subcortical network (e.g., Vuilleumier and Pourtois, 2007), involves visual processing in early visual areas, thereby affected by the loss of visual input and the modification of ocular exploration, but also cognitive processing in frontal regions that could be modified by cognitive bias (Marler and Ditton, 2021; Saunders et al., 2021). This latter factor could explain the difference in emotion recognition between the scarf and mask conditions (Aguillon-Hernandez et al., 2022). The preserved automatic processing of emotion in our study is observed in expert adults, but may not be observed in children, who are not yet face experts (Diamond and Carey, 1986).

In conclusion, this study is the first to evaluate the effect of facial accessories, and in particular the COVID-19 mask, on the visual exploration and physiological reactivity to ecological emotional faces. We have shown that the COVID-19 mask alters the ocular reading of the face, but with few specific effects compared to another accessory covering the lower part of the face. The physiological adjustment to observing a masked face is slightly disturbed, with a diminished and delayed pupil reactivity. The COVID-19 pandemic brought several concerns, and in particular diminished social interaction quantitatively and qualitatively. Our ocular and pupillary results on masked faces observation point toward only a slight deleterious effect of the mask, even if emotion recognition is affected (Aguillon-Hernandez et al., 2022). Beyond the COVID-19 pandemic, studying the influence of the mask is also primordial to better understand the doctor-patient relationship. Our results in adult participants suggest that even masked, a person can convey an emotional signal perceived implicitly by the observer.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by CPP, protocol PROSCEA 2017-A00756-47. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CW, NA-H, and ML contributed to conception and design of the study. VR and CR worked on technical settings and subject recruitment. VR acquired and processed the data and wrote the first draft of the manuscript. VR, NA-H, and CW performed the statistical analysis. CW and NA-H wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aguillon-Hernandez, N., Jusiak, R., Latinus, M., and Wardak, C. (2022). COVID-19 masks: A barrier to facial and vocal information. *Front. Neurosci.* 16:982899. doi: 10.3389/fnins.2022.982899

Aguillon-Hernandez, N., Mofid, Y., Latinus, M., Roché, L., Bufo, M. R., Lemaire, M., et al. (2020). The pupil: A window on social automatic processing in autism spectrum disorder children. *J. Child Psychol. Psychiatry* 61, 768–778.

Bassili, J. N. (1979). Emotion recognition: The role of facial movement and the relative importance of upper and lower areas of the face. *J. Pers. Soc. Psychol.* 37, 2049–2058. doi: 10.1037//0022-3514.37.11.2049

Blais, C., Jack, R. E., Scheepers, C., Fiset, D., and Caldara, R. (2008). Culture shapes how we look at faces. *PLoS One* 3:e3022. doi: 10.1371/journal.pone.0003022

Blais, C., Roy, C., Fiset, D., Arguin, M., and Gosselin, F. (2012). The eyes are not the window to basic emotions. *Neuropsychologia* 50, 2830–2838.

Bombari, D., Schmid, P. C., Schmid Mast, M., Birri, S., Mast, F. W., and Lobmaier, J. S. (2013). Emotion recognition: The role of featural and configural face information. *Q. J. Exp. Psychol.* 66, 2426–2442. doi: 10.1080/17470218.2013.789065

Bradley, M. M., Miccoli, L., Escrig, M. A., and Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology* 45, 602–607. doi: 10.1111/j.1469-8986.2008.00654.x

Bruce, V., and Young, A. (1986). Understanding face recognition. *Br. J. Psychol. Lond. Engl.* 77(Pt 3), 305–327. doi: 10.1111/j.2044-8295.1986.tb02199.x

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carey, S. (1992). Becoming a face expert. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 335, 95–102; discussion102–103. doi: 10.1098/rstb.1992.0012

Coutrot, A., Binetti, N., Harrison, C., Mareschal, I., and Johnston, A. (2016). Face exploration dynamics differentiate men and women. *J. Vis.* 16:16. doi: 10.1167/16.14.16

Davis, J. M., McKone, E., Dennett, H., O'Connor, K. B., O'Kearney, R., and Palermo, R. (2011). Individual differences in the ability to recognise facial identity are associated with social anxiety. *PLoS One* 6:e28800. doi: 10.1371/journal.pone.0028800

Diamond, R., and Carey, S. (1986). Why faces are and are not special: An effect of expertise. *J. Exp. Psychol. Gen.* 115, 107–117. doi: 10.1037//0096-3445.115.2.107

Ekman, P. (1992). Are there basic emotions? *Psychol. Rev.* 99, 550–553. doi: 10.1037/0033-295x.99.3.550

Fairhall, S. J., Dickson, C. A., Scott, L., and Pearce, P. C. (2006). A non-invasive method for studying an index of pupil diameter and visual performance in the rhesus monkey. *J. Med. Primatol.* 35, 67–77. doi: 10.1111/j.1600-0684.2005.00135.x

Flechsenhar, A. F., and Gamer, M. (2017). Top-down influence on gaze patterns in the presence of social features. *PLoS One* 12:e0183799. doi: 10.1371/journal.pone.0183799

Freud, E., Stajduhar, A., Rosenbaum, R. S., Avidan, G., and Ganel, T. (2020). The COVID-19 pandemic masks the way people perceive faces. *Sci. Rep.* 10:22344. doi: 10.1038/s41598-020-78986-9

Frith, C. (2009). Role of facial expressions in social interactions. *Philos. Trans. R. Soc. Lond. B. Biol. Sci.* 364, 3453–3458. doi: 10.1098/rstb.2009.0142

Graham, D. L., and Ritchie, K. L. (2019). Making a spectacle of yourself: The effect of glasses and sunglasses on face perception. *Perception* 48, 461–470. doi: 10.1177/0301006619844680

Guo, K. (2007). Initial fixation placement in face images is driven by top-down guidance. *Exp. Brain Res.* 181, 673–677. doi: 10.1007/s00221-007-1038-5

Guo, K. (2012). Holistic gaze strategy to categorize facial expression of varying intensities. *PLoS One* 7:e42585. doi: 10.1371/journal.pone.0042585

Hernandez, N., Metzger, A., Magné, R., Bonnet-Brilhault, F., Roux, S., Barthelemy, C., et al. (2009). Exploration of core features of a human face by healthy and autistic adults analyzed by visual scanning. *Neuropsychologia* 47, 1004–1012. doi: 10.1016/j.neuropsychologia.2008.10.023

Hsiao, J. H., Liao, W., and Tso, R. V. Y. (2022). Impact of mask use on face recognition: An eye-tracking study. *Cogn. Res. Princ. Implic.* 7:32. doi: 10.1186/s41235-022-00382-w

Johnson, M. H. (2005). Subcortical face processing. *Nat. Rev. Neurosci.* 6, 766–774. doi: 10.1038/nrn1766

Joshi, S., and Gold, J. I. (2020). Pupil size as a window on neural substrates of cognition. *Trends Cogn. Sci.* 24, 466–480. doi: 10.1016/j.tics.2020.03.005

Joshi, S., Li, Y., Kalwani, R. M., and Gold, J. I. (2016). Relationships between pupil diameter and neuronal activity in the locus coeruleus, colliculi, and cingulate cortex. *Neuron* 89, 221–234. doi: 10.1016/j.neuron.2015.11.028

Keil, M. S. (2009). "I look in your eyes, honey": Internal face features induce spatial frequency preference for human face processing. *PLoS Comput. Biol.* 5:e1000329. doi: 10.1371/journal.pcbi.1000329

Kotsia, I., Buciu, I., and Pitas, I. (2008). An analysis of facial expression recognition under partial facial image occlusion. *Image Vis. Comput.* 26, 1052–1067. doi: 10.1016/j.imavis.2007.11.004

Kret, M. E., and de Gelder, B. (2012). Islamic headdress influences how emotion is recognized from the eyes. *Front. Psychol.* 3:110. doi: 10.3389/fpsyg.2012.00110

Malcolm, G. L., Lanyon, L. J., Fugard, A. J. B., and Barton, J. J. S. (2008). Scan patterns during the processing of facial expression versus identity: An exploration of task-driven and stimulus-driven effects. *J. Vis.* 8, 2.1–2.9. doi: 10.1167/8.8.2

Marler, H., and Ditton, A. (2021). "I'm smiling back at you": Exploring the impact of mask wearing on communication in healthcare. *Int. J. Lang. Commun. Disord.* 56, 205–214. doi: 10.1111/1460-6984.12578

Martineau, J., Hernandez, N., Hiebel, L., Roché, L., Metzger, A., and Bonnet-Brilhault, F. (2011). Can pupil size and pupil responses during visual scanning contribute to the diagnosis of autism spectrum disorder in children? *J. Psychiatr. Res.* 45, 1077–1082. doi: 10.1016/j.jpsychires.2011.01.008

Mattavelli, G., Sormaz, M., Flack, T., Asghar, A. U. R., Fan, S., Frey, J., et al. (2014). Neural responses to facial expressions support the role of the amygdala in processing threat. *Soc. Cogn. Affect. Neurosci.* 9, 1684–1689. doi: 10.1093/scan/nst162

Maurer, D., Grand, R. L., and Mondloch, C. J. (2002). The many faces of configural processing. *Trends Cogn. Sci.* 6, 255–260. doi: 10.1016/S1364-6613(02)01903-4

Meaux, E., and Vuilleumier, P. (2016). Facing mixed emotions: Analytic and holistic perception of facial emotion expressions engages separate brain networks. *NeuroImage* 141, 154–173. doi: 10.1016/j.neuroimage.2016.07.004

Miellet, S., Vizioli, L., He, L., Zhou, X., and Caldara, R. (2013). Mapping face recognition information use across cultures. *Front. Psychol.* 4:34. doi: 10.3389/fpsyg.2013.00034

Morris, J. S., Ohman, A., and Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating "unseen" fear. *Proc. Natl. Acad. Sci. U.S.A.* 96, 1680–1685. doi: 10.1073/pnas.96.4.1680

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L. H., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Partala, T., Jokiniemi, M., and Surakka, V. (2000). "Pupillary responses to emotionally provocative stimuli," in *Proceedings of the 2000 symposium on Eye tracking research & applications ETRA '00*, (New York, NY: Association for Computing Machinery), 123–129. doi: 10.1145/355017.355042

Pesciarelli, F., Leo, I., and Sarlo, M. (2016). Implicit processing of the eyes and mouth: Evidence from human electrophysiology. *PLoS One* 11:e0147415. doi: 10.1371/journal.pone.0147415

Richoz, A.-R., Lao, J., Pascalis, O., and Caldara, R. (2018). Tracking the recognition of static and dynamic facial expressions of emotion across the life span. *J. Vis.* 18:5. doi: 10.1167/18.9.5

Roberson, D., Kikutani, M., Döge, P., Whitaker, L., and Majid, A. (2012). Shades of emotion: What the addition of sunglasses or masks to faces reveals about the development of facial expression processing. *Cognition* 125, 195–206. doi: 10.1016/j.cognition.2012.06.018

Saint, S. A., and Moscovitch, D. A. (2021). Effects of mask-wearing on social anxiety: An exploratory review. *Anxiety Stress Coping* 34, 487–502. doi: 10.1080/10615806.2021.1929936

Sara, S. J., and Bouret, S. (2012). Orienting and reorienting: The locus coeruleus mediates cognition through arousal. *Neuron* 76, 130–141. doi: 10.1016/j.neuron.2012.09.011

Saunders, G. H., Jackson, I. R., and Visram, A. S. (2021). Impacts of face coverings on communication: An indirect impact of COVID-19. *Int. J. Audiol.* 60, 495–506. doi: 10.1080/14992027.2020.1851401

Schurgin, M. W., Nelson, J., Iida, S., Ohira, H., Chiao, J. Y., and Franconeri, S. L. (2014). Eye movements during emotion recognition in faces. *J. Vis.* 14:14. doi: 10.1167/14.13.14

Schütt, H. H., Rothkegel, L. O. M., Trukenbrod, H. A., Engbert, R., and Wichmann, F. A. (2019). Disentangling bottom-up versus top-down and low-level versus high-level influences on eye movements over time. *J. Vis.* 19:1. doi: 10.1167/19.3.1

Straube, T., Mothes-Lasch, M., and Miltner, W. H. R. (2011). Neural mechanisms of the automatic processing of emotional information from faces and voices. *Br. J. Psychol. Lond. Engl.* 102, 830–848. doi: 10.1111/j.2044-8295.2011.02056.x

Treue, S. (2003). Visual attention: The where, what, how and why of saliency. *Curr. Opin. Neurobiol.* 13, 428–432. doi: 10.1016/s0959-4388(03)00105-3

Turati, C., Valenza, E., Leo, I., and Simion, F. (2005). Three-month-olds' visual preference for faces and its underlying visual processing mechanisms. *J. Exp. Child Psychol.* 90, 255–273. doi: 10.1016/j.jecp.2004.11.001

Vatikiotis-Bateson, E., Eigsti, I.-M., Yano, S., and Munhall, K. G. (1998). Eye movement of perceivers during audiovisualspeech perception. *Percept. Psychophys.* 60, 926–940. doi: 10.3758/BF03211929

Vuilleumier, P., and Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: Evidence from functional neuroimaging. *Neuropsychologia* 45, 174–194. doi: 10.1016/j.neuropsychologia.2006.06.003

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239. doi: 10.1371/journal.pone.0177239

Williams, L. M., Liddell, B. J., Kemp, A. H., Bryant, R. A., Meares, R. A., Peduto, A. S., et al. (2006). Amygdala-prefrontal dissociation of subliminal and supraliminal fear. *Hum. Brain Mapp.* 27, 652–661. doi: 10.1002/hbm.20208

World Medical Association (2013). World medical association declaration of helsinki: Ethical principles for medical research involving human subjects. *JAMA* 310, 2191–2194. doi: 10.1001/jama.2013.281053

Yrttiaho, S., Niehaus, D., Thomas, E., and Leppänen, J. M. (2017). Mothers' pupillary responses to infant facial expressions. *Behav. Brain Funct.* 13:2. doi: 10.1186/s12993-017-0120-9

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Masked face is looking at me: Face mask increases the feeling of being looked at during the COVID-19 pandemic

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Background: As the COVID-19 global pandemic unfolded, governments recommended wearing face masks as a protective measure. Recent studies have found that a face mask influences perception; but how it affects social perception, especially the judgment of being looked at, is still unknown. This study investigated how wearing a mask influences the judgment of gaze direction by conducting a cone of direct gaze (CoDG) task.

Methods: In Experiment 1, three types of masked faces were considered to investigate whether the effect of masks on CoDG is modulated by mask types. Experiment 2 was to further validate the results of Experiment 1 by adding a learning phase to help participants better distinguish N95 and surgical masks. Furthermore, to investigate whether the effect of masks derives from its social significance, a face with only the eye-region (a mouth-cut face) was used as the stimuli in Experiment 3.

Results: The results of Experiment 1 found that wearing masks widens the CoDG, irrespective of the mask type. Experiment 2 replicated the results of Experiment 1. Experiment 3 found that the CoDG of N95-masked faces was wider than the mouth-cut and non-masked faces, while no significant difference existed between the CoDG of mouth-cut and non-masked faces, illustrating that the influence of wearing masks on CoDG was due to high-level social significance rather than low-level facial feature information.

Conclusion: The results show that face mask increases the feeling of being looked at during the COVID-19 Pandemic. The present findings are of significance for understanding the impact of wearing masks on human social cognition in the context of COVID-19.

KEYWORDS

face mask, gaze direction, mask type, the cone of direct gaze (CoDG), COVID-19

Introduction

In 2019, a new infectious disease caused by the SARS-CoV-2 began spreading across the world. The World Health Organization (WHO) named it the coronavirus disease (COVID-19). Against the backdrop of the COVID-19 pandemic, wearing a mask has become a common phenomenon, since it is an important tool to effectively block the spread of the droplets that cause this disease. However, wearing a mask may have negative effects as well. Some studies recruited normal adults as participants and have found that masks provide a somewhat obscuring effect on the face, as they cover the nose and mouth areas of the wearer's face, which is believed to affect the recognition of facial emotions (Carbon, 2020; Noyes et al., 2021) and influences one's judgment of the wearer's trustworthiness (Cartaud et al., 2020).

Cone of direct gaze is an index of the feeling of being looked at

The eye region, a facial area that is not covered by masks, shows the direction of eye gaze and can provide important information such as attentional location, behavioral intention, and emotional state (Emery, 2000; Mareschal et al., 2013b, 2014). Perceiving that a person is looking at us (Bateson et al., 2006; Carbon and Hesslinger, 2011; Hamilton, 2016), or looking away from us (Hietanen et al., 2008; Colombatto et al., 2020), has different effects on our behavior and perception. Therefore, an accurate perception of the gaze direction of one's eyes is crucial to social interaction. However, previous studies have found that the perception of one's gaze direction may not be very accurate. Humans prefer to judge others by looking at them (Mareschal et al., 2013a). To measure this tendency, Jun et al. (2013) conducted a study where participants were instructed to judge whether they perceived the gaze on faces looking in various directions to be looking at them. This index is commonly known as the cone of direct gaze (CoDG) (Gamer and Hecht, 2007; Jun et al., 2013). The wider the CoDG, the more the participant perceived the face as "looking at me."

Factors influencing cone of direct gaze

Although CoDG is a relatively stable indicator for individuals (Lobmaier et al., 2021), it is influenced by a variety of factors. Firstly, facial information, such as head orientation (Gamer and Hecht, 2007), facial attractiveness (Kloth et al., 2011), facial expressions (Ewbank et al., 2009; Gillian et al., 2012), and so on, can influence CoDG. Secondly, CoDG is also affected by individual differences among the participants. People with autistic traits are less likely to judge being looked at, which means their CoDG is narrower (Matsuyoshi et al., 2014). Anxious individuals (Harbort et al., 2013) and schizophrenic patients (Wastler and Lenzenweger, 2018) are more inclined to judge someone looking at them as compared to others, meaning that their CoDG is wider. In addition, a recent study found that emotional situations may also affect CoDG (Rimmele and Lobmaier, 2012; Lyyra et al., 2017; Syrjämäki et al., 2017). Specifically, external pressure affects perceptual judgments of being looked at; being socially excluded increases one's judgment of being looked at if there is a possibility of re-interaction (Lyyra et al., 2017) while it deceases if there is no interaction (Syrjämäki et al., 2017).

The current study

To sum up, CoDG is affected by emotional situations and wearing a mask can create a safe or a threatening situation, especially in the context of the COVID-19 outbreak. Thus, a CoDG task was conducted to examine how wearing a mask impacts the judgment of gaze direction. Different types of masks create different levels of perception of danger or safety (Chu et al., 2020). For example, N95 masks provide a higher level of protection from viruses than regular surgical masks. Unlike a surgical mask, an N95 one may be more likely to convey the message that the virus will not be spread by the individual wearing it. At the same time, wearing N95 masks may also mean that the surrounding environment is dangerous and the likelihood of infection is high. Therefore, three types of masked faces (non-masked faces, surgical-masked faces, and N95-masked faces) were considered in our study to further explore whether the effect of masks on CoDG is modulated by the type of mask being used. In addition, to investigate whether the impact of masks on CoDG was related to COVID-19 or a person's individual characteristics, we asked the participants to complete a three-item questionnaire on COVID-19, Social Interaction Anxiety Scale (SIAS) (Mattick and Clarke, 1998), and Self-Rating Depression Scale (SDS) (Zung et al., 1965), after the CoDG task.

Given that previous research has already shown that wearing a mask can reduce social distance and increase willingness to socialize in the context of the COVID-19 pandemic (Cartaud et al., 2020), we predicted that participants will over-report their sensation of being looked at. Namely, the CoDG of the masked faces will be wider than that of the unmasked faces. In addition, previous studies have found that while trustworthiness or threat can widen the CoDG, wearing a mask may enhance the wearer's sense of trustworthiness or threat. Thus, we predict that N95-masked faces may produce a wider CoDG than a face wearing a regular surgical mask.

Experiment 1

Methods

Participants

An *a priori* power analysis (G*Power 3; Faul et al., 2007) with a medium effect size of 0.25, a 1-β power of 0.80, and an alpha of 0.05 found that the required number of participants in the study should be 28. In addition, the sample size in similar studies has been restricted to 20–40 participants (Ewbank et al., 2009; Pantelis and Kennedy, 2016; Lyyra et al., 2017; Awad et al., 2019). Thus, we expected to test 30 participants. When 30 participants were tested, we found that a large number of participants would have to be excluded due to fitting failure (see section "Data analyses" for details). Finally, we expanded the number of participants to 40 (14 males, 26 females), aged 18–23 years ($M = 19.6$ $SD = 1.08$). All the participants had normal or corrected-to-normal vision and self-reported absence of mental illness. The study was approved by the ethics committee of the Institute of Brain and Psychological Sciences, Sichuan Normal University [SCNU-210520]. All the participants provided their written informed consent to take part in this study and received monetary compensation for their participation (see **Supplementary Appendix 1**). This study was not pre-registered.

Stimuli, materials, and apparatus

The colored, full-face images of six Chinese adult models (3 males, 3 females) were taken using a camera. The models were asked to keep their faces neutral and change their gaze direction continuously at 11 gaze deflection angles (2°, 4°, 6°, 8°, 10° each to the left and right, and 0°) without making any other movement. To exclude the influence of color on the experimental results, we set the color of both masks as white. The models were required to repeat the procedure in their masked condition, wearing a surgical mask or an N95 mask.

All the photographs were edited using Photoshop CS6 (596 × 596 pixels), keeping all the faces consistent in terms of brightness and contrast, maintaining a gray background (see **Figure 1**).

The experiment was conducted on a 24-inch (1,920 by 1,080 pixels; 60 Hz refresh rate) LCD monitor. Stimulus presentations and recordings of the behavioral measures were controlled by E-prime 2.0.

Task and procedure

A 3 (face type: non-masked faces, surgical-masked faces, N95-masked faces) × 11 (gaze direction: 2°, 4°, 6°, 8°, 10° each to the left and right, and 0°) within-subjects design was used. The participants were seated comfortably in a dimly lit room where they received written instructions for the CoDG task. They sat at a distance of ~60 cm from a LCD monitor. Lighting conditions were kept constant for all the participants and the screen position was manually adapted so that the eyes of the avatars were vertically aligned with the eyes of the participants.

Each trial began with a fixation cross presented on the screen for 1,000 ms. Next, a face with or without a mask was presented, which remained on the screen until the participant's response. This was followed by a 500 ms blank screen, after which the next trial began. The participants were required to identify the gaze direction by pressing the keyboard (with 1 meaning that "the face is watching my left," 2 referring to "the face is watching me," and 3 meaning that "the face is watching my right"). Although each model had faces wearing three types of masks, each participant observed the faces of each model wearing only one type of mask. It was ensured that the face type matched the model for each participant. The binding of a mask to a model's identity was randomized and balanced among the participants. The presentation sequences of the faces were also random. Each participant completed a total of 594 trials (18 trials per face type × gaze direction). The whole procedure lasted 30 min. After the CoDG task, the participants were instructed to fill three self-assessment questionnaires pertaining to COVID-19, SIAS, and SDS.

Data analyses

The cones of direct gaze were measured using conventional methods. The data were separated into different mask conditions, resulting in three data sets (non-masked faces, surgical-masked faces, N95-masked faces) (see **Figure 2A**). For each condition, logistic functions were fitted to the proportion of *left* and *right* responses. A function for *direct* responses was calculated by subtracting the sum of the *left* and *right* responses from 1. These three functions were fitted as an ensemble using the Nelder-Mead simplex method (Nelder and Mead, 1965), implemented using the Matlab's fminsearch function to minimize the residual variance. The cone of direct gaze was calculated as the distance (in degrees of gaze deviation) between the points of intersection (termed categorical boundaries) of the two averted curves with the *direct* curve: one where the *left* and *direct* responses crossed each other and the other where the *direct* and *right* responses intersected.

Ten participants were excluded finally because their response curves were too broad to allow confident estimations of the width of their CoDG, remaining 30 participants' data (10 males, 20 females) for the statistical analysis.

Results and discussion

Cone of direct gaze

A one-way repeated-measures ANOVA test showed a significant main effect of the face type on the CoDG, [$F(2, 58) = 6.20$, $p = 0.004$, $\eta_p^2 = 0.176$] (see **Table 1**). A Bonferroni *post-hoc* test found that the CoDG for N95-masked faces and surgical-masked faces were higher as compared to the non-masked faces, $p = 0.001$, $p = 0.036$. However, there was no

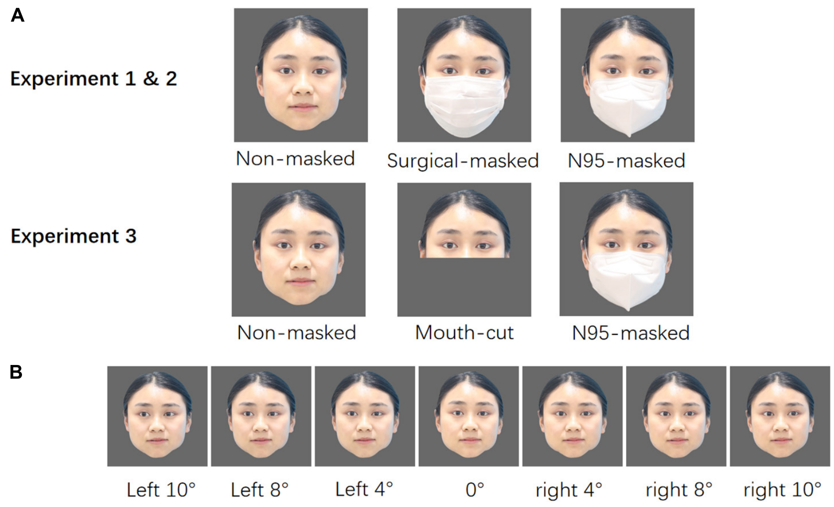

FIGURE 1
(A) Sample of a female model displaying the three face types used in Experiments 1, 2 and 3. **(B)** Sample of a female model displaying the seven gaze directions: 4°, 8°, 10° each to the left and right, and 0°. Written informed consent was obtained from the model for the publication of her images in this article.

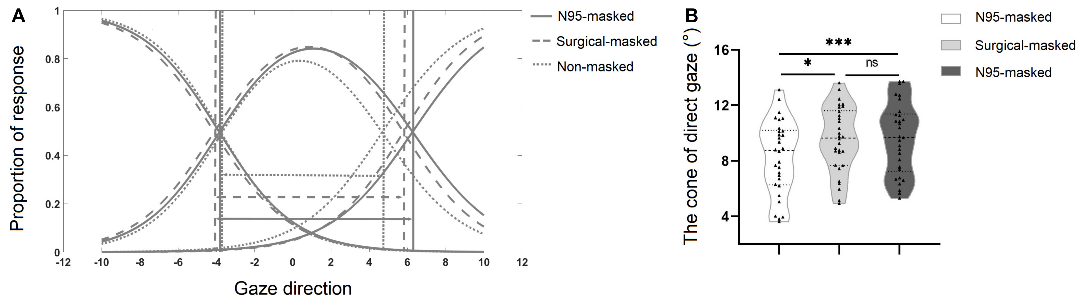

FIGURE 2
(A) Plot showing the mean fitted logistic functions for *left*, *right*, and *direct* responses. The solid lines indicate the N95-masked face condition, the dashed lines indicate the surgical-masked face condition, while the dotted lines indicate the non-masked faces condition. The arrows indicate the width of the cone of direct gaze. **(B)** The mean width of the cone for non-masked face, surgical-masked face, and N95-masked face conditions. ▲ Indicated data for each participant. *$p < 0.05$, ***$p < 0.001$, ns $p > 0.05$.

significant difference between the CoDG for surgical-masked faces and N95-masked faces, $p > 0.05$ (see Figure 2B).

Correlations between cone of direct gaze and questionnaires

To assess the relationship between the CoDG and the participants' knowledge about masks as well as between the CoDG and traits of anxiety and depression, we calculated Pearson correlations between the CoDG of a particular face type and the participants' responses to questions about face masks, SDS, and SIAS. Bonferroni correction revealed there was no significant correlation, $ps > 0.05$ (see Supplementary Appendix 2).

The results of Experiment 1 showed that wearing masks widened one's CoDG significantly. Individuals were more likely to judge that a face wearing a mask was looking at them. Contrary to our expectations, there was no significant difference in the CoDG of N95-masked faces and surgical-masked faces, suggesting that the mask type does not affect the CoDG.

Experiment 2

No effect of different types of face masks on CoDG was found in Experiment 1. One possible explanation is that individuals are not able to distinguish between surgical masks and N95 masks in terms of function and appearance. To rule out this possibility, in Experiment 2, we set up a learning phase to deepen the cognition of the difference between a surgical mask and the N95 mask. The purpose of Experiment 2 was to explore further whether mask type affects the perception of being gazed at. Importantly, by analyzing the 10 excluded data

TABLE 1 The CoDG (mean ± SD) on Experiments 1, 2 and 3.

	Experiment 1	Experiment 2	Experiment 3
Non-masked face	8.26 ± 2.67	8.06 ± 2.70	8.57 ± 2.39
Surgical-masked face	9.52 ± 2.36	8.86 ± 2.69	/
N95-masked face	9.60 ± 2.57	8.84 ± 2.65	9.61 ± 2.20
Mouth-cut face	/	/	8.98 ± 2.19

in Experiment 1, it was found that these participants' CoDGs were too wide and could not be fitted mainly because the proportion of participants judging the gaze direction as averted gaze was too low under the condition of left and right 10°. Therefore, in order to reduce the exclusion rate of participants, we added the conditions that gaze direction was left and right 12°in Experiment 2.

Methods

Participants

Referring to the valid data amount of Experiment 1 and considering that the addition of gaze direction levels (looking at left and right 12° levels were added under gaze direction variable) in Experiment 2 would result in less participant data exclusion, we recruited 31 new participants (10 males, 21 females), aged 18–22 years ($M = 20.25$ $SD = 1.04$), none of whom had participated in Experiment 1. All the participants had normal or corrected-to-normal vision and self-reported absence of mental illness.

Stimuli and procedure

The same model pictures used in Experiment 1 were used in Experiment 2 as well, though the pictures of two models (1 male, 1 female) were excluded to accommodate the new design. Similar to Experiment 1, each model displayed a neutral expression which either had 0° (direct gaze), 2°, 4°, 6°, 8°, 10°, or 12° shift of gaze to the right or left (averted gaze).

The entire experiment consisted of two sequential parts: the learning task and CoDG task. In the learning phase, the participants were presented with the knowledge comparison of N95 masks and surgical masks, including three aspects: filtration layer, protection effect and recommended wearing place. 20s later, the participants were presented with the shape of both masks, so that they could be familiar with the shape of different mask types (10s), and finally 5 test questions were presented to test the learning effect of the participants.

The CoDG task procedure was consistent with Experiment 1, except each participant observed three face types for each model. Each participant completed a total of 624 trials (16 trials per face type × gaze direction). The whole experiment lasted about 30 min.

The data analysis was identical to Experiment 1. Four participants were excluded because their response curves were too broad to allow confident estimations of the width of their CoDG, leaving data from 27 participants to be studied in the statistical analysis (7 males, 20 females). The others are the same as Experiment 1.

Results and discussion

Cone of direct gaze

ANOVA test showed a significant main effect of the face type on CoDG, [$F(2, 52) = 12.74$, $p < 0.001$, $\eta_p^2 = 0.329$] (see **Table 1**). A Bonferroni corrected *post hoc* test found that the CoDG for N95-masked faces and surgical-masked faces were higher as compared to the non-masked faces, $ps < 0.001$. However, there was no significant difference between the CoDG for surgical-masked faces and N95-masked faces, $p > 0.05$ (see **Figure 3**).

Correlations between cone of direct gaze and questionnaires

To assess the relationship between the CoDG and the participants' knowledge about masks as well as between the CoDG and traits of anxiety and depression, we calculated Pearson correlations between the CoDG of a particular face type and the participants' responses to questions about face masks, SDS, and SIAS. The Bonferroni correction revealed there was no significant correlation, $ps > 0.05$ (see **Supplementary Appendix 2**).

Experiment 2 replicated the results of Experiment 1 and found that the CoDG for N95-masked faces was significantly wider than that for the non-masked faces, suggesting that wearing masks made individuals judge being looked at more.

Experiment 3

The results of Experiment 1 and 2 showed that wearing a mask widens the CoDG. One possibility behind this is the significant difference in the social significance of masked and unmasked faces. In social interactions, masked faces are more likely to convey that the mask-wearer is safer to others or the surrounding environment is more threatening as compared to unmasked faces (Tateo, 2021). However, in addition to the difference in social significance, there are differences in the low-level facial features of masked and unmasked faces as well. Unmasked faces have their complete facial features intact and in view while masked faces, due to the physical barrier caused by masks, prevent the viewer from gathering information about

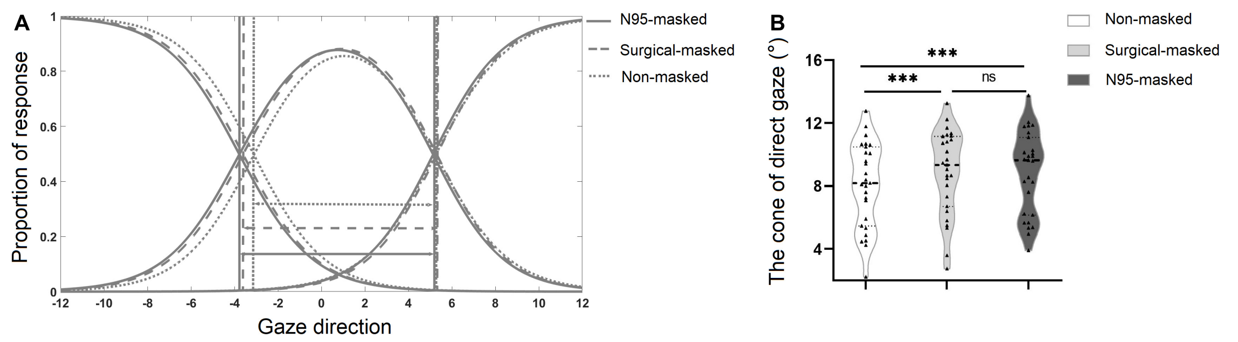

FIGURE 3
(A) Plot showing the mean fitted logistic functions for *left*, *right*, and *direct* responses. The solid lines indicate the N95-masked face condition, the dashed lines indicate the surgical-masked face condition, while the dotted lines indicate the non-masked faces condition. The arrows indicate the width of the cone of direct gaze. **(B)** The mean width of the cone for non-masked face, surgical-masked face, and N95-masked face conditions. ▲ Indicated data for each participant. ***$p < 0.001$, ns $p > 0.05$.

the person's mouth. Previous studies have found that the lower part of the face also conveys a lot of information (Robert and Adam, 2016) and that mask coverings can impact cognitive processing based on information from the part (Carbon, 2020; Noyes et al., 2021). Therefore, there may be another explanation for the results of Experiment 1 and 2. The lack of information related to the mouth obstructs the information processing of masked faces, making it less accurate for individuals to judge eye gaze information and leading them to interpret a more averted gaze as a direct one, thus widening the CoDG. Hence, in Experiment 3, faces with the mouth edited out were employed to address whether the influence of wearing masks on CoDG is a result of the difference in the social significance between masked and non-masked faces or if it is a result of the difference in facial feature information. If the effect of wearing masks on CoDG is derived from the low-level facial feature information, we should observe that the mouth-cut faces have a CoDG that is similar to the N95-masked faces and significantly larger than non-masked faces. If the CoDG of the mouth-cut faces are similar to that of the non-masked faces, and both of their CoDGs are smaller than that of the N95-masked faces, it will indicate that the influence of wearing masks on CoDG is mainly due to the high-level social significance of masked faces.

Methods

Participants

Referring to the valid data amount of Experiment 1 and 2, we recruited 37 new participants (15 males, 22 females), aged 18–30 years ($M = 20.3$ $SD = 2.05$), none of whom had participated in either Experiment 1 or Experiment 2. All the participants had normal or corrected-to-normal vision and self-reported absence of mental illness. The others are the same as Experiment 1.

Stimuli and procedure

We created mouth-cut faces by editing out the lower part of the models' faces (see **Figure 1**). The same model pictures used in Experiment 2 was used in Experiment 3 as well.

The procedure was consistent with Experiment 1, except that each participant viewed all the faces of one model under three conditions (non-masked face, mouth-cut face, and N95-masked face). Each participant completed a total of 624 trials (16 trials per face type × gaze direction). The whole experiment lasted about 30 min.

The procedure of CoDG task and data analysis were identical to Experiment 1.

The data analysis was identical to Experiment 1. Seven participants were excluded because their response curves were too broad to allow confident estimations of the width of their CoDG, leaving data from 30 participants to be studied in the statistical analysis (10 males, 20 females).

Results and discussion

Cone of direct gaze

A one-way repeated-measures ANOVA test showed significant main effect of the condition of the face on the CoDG, [$F(1.47, 42.58) = 10.61$, $p < 0.001$, $\eta_p^2 = 0.268$] (see **Table 1**). A Bonferroni corrected *post hoc* test found that the CoDG of N95-masked faces was higher than the mouth-cut faces and non-masked faces, *ps* < 0.001. However, there was no significant difference between the mouth-cut faces and non-masked faces, $p > 0.05$ (see **Figure 4**).

Correlations between cone of direct gaze and questionnaires

To test the relation between the widening of the CoDG and the self-assessment questionnaires, we calculated the Pearson's correlation coefficients under two conditions, N95-masked

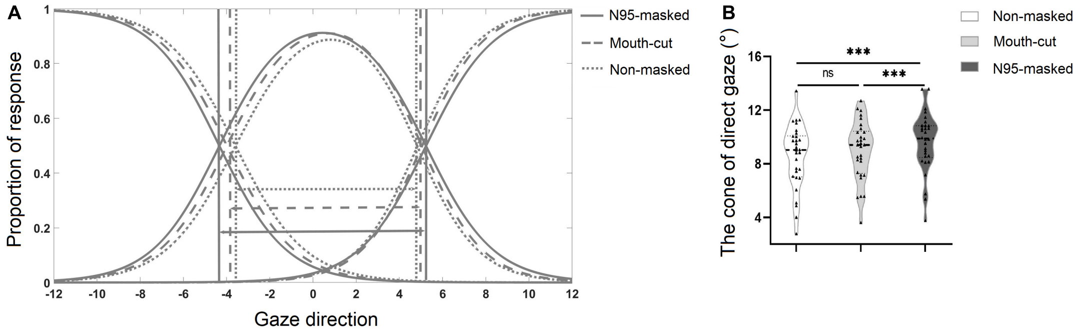

FIGURE 4
(A) Plot showing the mean fitted logistic functions for *left*, *right*, and *direct* responses for N95-masked face, mouth-cut face and non-masked face conditions. The solid lines indicate the N95-masked face condition, the dashed lines indicate the mouth-cut face condition, and the dotted lines indicate non-masked face condition. The arrows indicate the width of the cone of gaze. **(B)** The mean width of the cone for the non-masked, mouth-cut, and N95 -masked conditions. ▲ Indicated data for each participant. ***$p < 0.001$, ns $p > 0.05$.

minus non-masked and the CoDG obtained when the value of the non-mask faces is subtracted from that of mouth-cut faces (mouth-cut minus non-masked face), drawing on the answers to the COVID-19 questionnaire (Q1, Q2, and Q3), the SIAS score, and the SDS score. Bonferroni correction revealed there was no significant correlation, $ps > 0.05$ (see **Supplementary Appendix 2**).

To further examine the relationship between the widening CoDG caused by wearing N95 masks and the self-assessment questionnaires, we combined the data from Experiments 1, 2 and 3 under the N95-masked face and non-masked face conditions and calculated the Pearson's correlation coefficient for N95-masked minus non-masked, drawing on the answers to the COVID-19 questionnaire (Q1, Q2, and Q3), the SIAS score, and the SDS score. There was no significant negative correlation between questionnaires and the widening effect, $ps > 0.05$ (see **Supplementary Appendix 2**).

Experiment 3 replicated the results of Experiment 1 and 2 and found that the CoDG for N95-masked faces was significantly wider than that for the non-masked faces, suggesting that wearing masks made individuals judge being looked at more. Notably, we found that the CoDG for mouth-cut faces was narrower than that for N95-masked faces while no significant difference was found between the CoDG of mouth-cut faces and non-masked faces. This finding indicated that the influence of wearing masks on the CoDG is due to its high-level social significance rather than the low-level facial feature information.

General discussion

We conducted a gaze discrimination study to investigate the influence of wearing masks on CoDG. The results showed that wearing masks increases the width of CoDG. We also found that the CoDG of masked faces was significantly wider than that of unmasked faces. This indicated that wearing a mask would affect the processing of gaze direction. However, mouth-cut faces did not produce the same widening effect on CoDG as the masked faces. These findings show that the influence of masks on CoDG can mainly be attributed to the high-level social significance of wearing a mask, rather than the low-level physical information of the face.

Why does wearing a mask influence the judgment of gaze direction? One possible explanation is that wearing face masks increases the sense of trust and, thus, widens the CoDG. During the COVID-19 pandemic, most governments as well as the WHO recommended wearing face masks as a key measure to protect people from the novel coronavirus (Bhardwaj and Agrawal, 2020; Carbon, 2020). In addition, studies have found that, in the context of COVID-19, a face covered by a mask may be considered safer and more trustworthy (Cartaud et al., 2020). The increase in trust makes people willing to interact and, thus, more likely to judge that a face wearing a mask is looking at them. On the contrary, another explanation is that wearing face masks increases the sense of threat and, thus, widens the CoDG. During the COVID-19 pandemic, wearing face masks implies a risk of COVID-19 transmission for the wearer probably being a COVID-19 patient. Consequently, the mask could be perceived as a threat message highly relevant to one's health. When facing threatening facial expressions or in a threatening situation, previous studies have shown that people tend to judge others as looking at them, resulting in a wider CoDG (Ewbank et al., 2009; Tso et al., 2012; Jun et al., 2013; Harbort et al., 2017). Previous studies have found that masks both increase trust and shorten the social distance, but also increase perceptions of sickness, possibly because the internalized rule of wearing a mask inhibits automatic evaluation of mistrust (Rosa, 2020).

The result of these two contradictions may be that people themselves may hold ambivalent attitudes toward masks. From a cultural psychological perspective, in the context of the COVID-19 pandemic, masks are given some social significance and are no longer neutral objects. Meanwhile, the mask becomes part of the body by covering the nose and mouth areas. It is an interface that simultaneously distances and connects me to the other. By wearing a mask, the person generates different levels of meaning and automatic hetero-regulatory processes (Tateo, 2021). Therefore, we did not specifically discuss whether the widening effect is due to an increased sense of security or threat from masks during the COVID-19 pandemic.

Besides, no significant impact of the mask types on the CoDG emerged; as the same widening effect on the CoDG was observed for both the N95-masked faces and surgical-masked faces. On the one hand, during the pandemic, people have been highly sensitive to the threatening information about COVID-19. As for information about the level of threat, masks that offer lower protection (surgical-masked) and those that offer higher protection (N95-masked) can induce the alert response from individuals. Therefore, the N95-masked and surgical-masked faces have the same widening effect. Apparently, such an undifferentiated alert response has adaptive significance for human survival. To give an example, although there was a difference in the feasibility of transmitting the virus between COVID-19 patients and those who had recovered, there was no difference in viewing time to their faces (Federico et al., 2021). In general, individuals have the same avoidance response to novel coronavirus-related information at different threat levels.

On the other hand, there is no significant difference in the cognition of mask protection in the individual's perception. This may have something to do with advice circulated by the media to the general public to wear face masks during the pandemic, that both surgical masks and N95 masks provide adequate protection against novel coronavirus transmission through droplets (Sureka et al., 2020). Furthermore, people are equally familiar with and are likely to be exposed to both types of masks. Consequently, this may result in the inability to observe the different effects of mask types in our study. Future studies may use more diverse mask types having different protective characteristics (such as gauze masks vs. N95 masks) to further explore this issue.

The present study did not find any correlation between the three-item questionnaire on COVID-19 and scale and the mask effect, which was consistent with the results of previous studies (Lobmaier et al., 2021). The correlation results might be related to the sample size, and future studies could use larger samples to verify the correlation between individual traits and the mask effect. Another possible reason was that our participants were selected from college students and did not include clinically diagnosed patients, so masking the correlation between the questionnaire and CoDG. This could be further explored in the future by selecting clinical participants.

Another key point to remember is that there were some limitations in the participant selection process, since all of them were recruited from college. Inevitably, age and knowledge of background may have influenced their gaze judgments. Considering this, it would be useful for future studies to recruit people of different ages and backgrounds. It must also be noted that the participants were all Chinese. Previous studies have reported the significance of the culture of face masks (Timpka and Nyce, 2021) and different cultural effects on the perception of facial information (Blais et al., 2008; Jack et al., 2009). Meanwhile, during the COVID-pandemic, different cultures took different measures and also showed different attitudes to wearing masks. As such, further studies are required to compare the effects of face masks on gaze perceptions in different cultures. In addition, considering that taking physical masking approaches would introduce new variables (e.g., color, personal preference, etc.), the current study created mouth-cut faces by editing out the lower part of the models' faces as the control condition. However, this operation could disrupt the integrity of a face. Previous studies found the presentation of a whole face affects the processing of face information (Leder and Carbon, 2005). Thus, further studies could seek out a better control condition to explore the widening effect of face masked on CoDG.

Furthermore, with the global outbreak of COVID-19 pandemic and the virus mutating, people have become fully aware of the seriousness of the epidemic and the wearing of masks has become widely recognized during the period of data collection (March 2021 to December 2021). Many countries have now announced the removal of epidemic prevention and control measures, and it is possible that people's perceptions of masks may vary, so the results may not apply to those who are not required to wear them.

Conclusion

The current study adapted a gaze direction judgment methodology to measure the influence of masks on CoDG. The results provide novel evidence linking the wearing of masks to the widening of an individual's CoDG. Furthermore, the widening effect may be related to the social meaning induced by face mask, rather than physical barrier. The frequency with which individuals wear masks during the COVID-19 pandemic may reduce the influence of masks on the CoDG. In addition, it was found that the mask type does not regulate the effect of the mask on the CoDG. This study has significant implications for understanding the impact of wearing masks on human social perceptions in the backdrop of COVID-19.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of the Institute of Brain and Psychological Sciences, Sichuan Normal University. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the model for the publication of her images in this article.

Author contributions

ZH conceived and designed the experiments. JL, LH, LZ, and JX performed the data acquisition and analyzed the data. JL, ZH, and JY interpreted the data and drafted the manuscript. All authors revised and approved the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnins.2022.1056793/full#supplementary-material

References

Awad, D., Emery, N. J., and Mareschal, I. (2019). The role of emotional expression and eccentricity on gaze perception. *Front. Psychol.* 10:1129. doi: 10.3389/fpsyg.2019.01129

Bateson, M., Nettle, D., and Roberts, G. (2006). Cues of being watched enhance cooperation in a real-world setting. *Biol. Lett.* 2, 412–414. doi: 10.1098/rsbl.2006.0509

Bhardwaj, R., and Agrawal, A. (2020). Tailoring surface wettability to reduce chances of infection of COVID-19 by a respiratory droplet and to improve the effectiveness of personal protection equipment. *Physics Fluids* 32:081702. doi: 10.1063/5.0020249

Blais, C., Jack, R. E., Scheepers, C., Fiset, D., and Caldara, R. (2008). Culture shapes how we look at faces. *PLoS One* 3:e3022. doi: 10.1371/journal.pone.0003022

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Carbon, C.-C., and Hesslinger, V. M. (2011). Cues-of-being-watched paradigm revisited. *Swiss J. Psychol.* 70, 203–210. doi: 10.1024/1421-0185/a000058

Cartaud, A., Quesque, F., and Coello, Y. (2020). Wearing a face mask against COVID-19 results in a reduction of social distancing. *PLoS One* 15:e0243023. doi: 10.1371/journal.pone.0243023

Chu, D. K., Akl, E. A., Duda, S., Solo, K., Yaacoub, S., Schünemann, H. J., et al. (2020). Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: A systematic review and meta-analysis. *Lancet* 395, 1973–1987. doi: 10.1016/S0140-6736(20)31142-9

Colombatto, C., Chen, Y.-C., and Scholl, B. J. (2020). Gaze deflection reveals how gaze cueing is tuned to extract the mind behind the eyes. *Proc. Natl. Acad. Sci. U.S.A.* 117, 19825–19829. doi: 10.1073/pnas.2010841117

Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neurosci. Biobehav. Rev.* 24, 581–604. doi: 10.1016/S0149-7634(00)00025-7

Ewbank, M. P., Jennings, C., and Calder, A. J. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *J. Vis.* 9, 1–7. doi: 10.1167/9.12.16

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Federico, G., Ferrante, D., Marcatto, F., and Brandimonte, M. A. (2021). How the fear of COVID-19 changed the way we look at human faces. *PeerJ* 9:e11380. doi: 10.7717/peerj.11380

Gamer, M., and Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *J. Exp. Psychol. Hum. Percept. Perform.* 33, 705–715. doi: 10.1037/0096-1523.33.3.705

Gillian, R., Brooke, A., Linda, J., Michael, E., Calder, A. J., and Sun, H. J. (2012). Facial expressions of threat influence perceived gaze direction in 8 year-olds. *PLoS One* 7:e49317. doi: 10.1371/journal.pone.0049317

Hamilton, A. (2016). Gazing at me: The importance of social meaning in understanding direct-gaze cues. *Philos. Trans. R. Soc. London* 371:20150080. doi: 10.1098/rstb.2015.0080

Harbort, J., Spiegel, J., Witthft, M., and Hecht, H. (2017). The effects of social pressure and emotional expression on the cone of gaze in patients with social anxiety disorder. *J. Behav. Ther. Exp. Psychiatry* 55, 16–24. doi: 10.1016/j.jbtep.2016.11.004

Harbort, J., Witthöft, M., Spiegel, J., Nick, K., and Hecht, H. (2013). The widening of the gaze cone in patients with social anxiety disorder and its normalization after CBT. *Behav. Res. Ther.* 51, 359–367. doi: 10.1016/j.brat.2013.03.009

Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., and Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach–avoidance motivational brain systems. *Neuropsychologia* 46, 2423–2430. doi: 10.1016/j.neuropsychologia.2008.02.029

Jack, R. E., Blais, C., Scheepers, C., Schyns, P. G., and Caldara, R. (2009). Cultural confusions show that facial expressions are not universal. *Curr. Biol.* 19, 1543–1548. doi: 10.1016/j.cub.2009.07.051

Jun, Y. Y., Mareschal, I., Clifford, C. W. G., and Dadds, M. R. (2013). Cone of direct gaze as a marker of social anxiety in males. *Psychiatry Res.* 210, 193–198. doi: 10.1016/j.psychres.2013.05.020

Kloth, N., Altmann, C. S., and Schweinberger, S. R. (2011). Facial attractiveness biases the perception of eye contact. *Quart. J. Exp. Psychol.* 64, 1906–1918. doi: 10.1080/17470218.2011.587254

Leder, H., and Carbon, C.-C. (2005). When context hinders! Learn–test compatibility in face recognition. *Quart. J. Exp. Psychol. Sec. A* 58, 235–250. doi: 10.1080/02724980343000936

Lobmaier, J. S., Savic, B., Baumgartner, T., and Knoch, D. (2021). The cone of direct gaze: A stable trait. *Front. Psychol.* 12:682395. doi: 10.3389/fpsyg.2021.682395

Lyyra, P., Wirth, J. H., and Hietanen, J. K. (2017). Are you looking my way? Ostracism widens the cone of gaze. *Quart. J. Exp. Psychol.* 70, 1713–1721. doi: 10.1080/17470218.2016.1204327

Mareschal, I., Calder, A. J., and Clifford, C. W. G. (2013a). Humans have an expectation that gaze is directed toward them. *Curr. Biol.* 23, 717–721. doi: 10.1016/j.cub.2013.03.030

Mareschal, I., Calder, A. J., Dadds, M. R., and Clifford, C. W. G. (2013b). Gaze categorization under uncertainty: Psychophysics and modeling. *J. Vis.* 13:18. doi: 10.1167/13.5.18

Mareschal, I., Otsuka, Y., and Clifford, C. W. G. (2014). A generalized tendency toward direct gaze with uncertainty. *J. Vis.* 14, 27–27. doi: 10.1167/14.12.27

Matsuyoshi, D., Kuraguchi, K., Tanaka, Y., Uchida, S., Ashida, H., and Watanabe, K. (2014). Individual differences in autistic traits predict the perception of direct gaze for males, but not for females. *Mol. Autism* 5:12. doi: 10.1186/2040-2392-5-12

Mattick, R. P., and Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav. Res. Ther*. 36, 455–470. doi: 10.1016/s0005-7967(97)10031-6

Nelder, J. A., and Mead, R. (1965). A simplex method for function minimization. *Comput. J.* 7, 308–313. doi: 10.1093/comjnl/7.4.308

Noyes, E., Davis, J. P., Petrov, N., Gray, K., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Pantelis, P. C., and Kennedy, D. P. (2016). Prior expectations about where other people are likely to direct their attention systematically influence gaze perception. *J. Vis.* 16:7. doi: 10.1167/16.3.7

Rimmele, U., and Lobmaier, J. S. (2012). Stress increases the feeling of being looked at. *Psychoneuroendocrinology* 37, 292–298. doi: 10.1016/j.psyneuen.2011.06.013

Robert, S., and Adam, W. (2016). "Mouth features extraction for emotion classification," in *2016 Federated Conference on Computer Science and Information Systems (FedCSIS)*, (IEEE: Gdansk, PL). 1685–1692.

Rosa, A. O.-L. (2020). Keep your (social) distance Pathogen concerns and social perception in the time of COVID-19. *Personal. Individ. Diff.* 166:110200. doi: 10.1016/j.paid.2020.110200

Sureka, B., Garg, M., and Misra, S. (2020). N95 respirator and surgical mask in the pandemic of COVID-19. *Ann. Thoracic Med.* 15:247. doi: 10.4103/atm.ATM_264_20

Syrjämäki, A. H., Lyyra, P., Peltola, M. J., and Hietanen, J. K. (2017). When a look is not enough: No evidence for direct gaze facilitating recovery after social exclusion. *Soc. Cogn.* 35, 601–618. doi: 10.1521/soco.2017.35.6.601

Tateo, L. (2021). Face masks as layers of meaning in times of COVID-19. *Cult. Psychol.* 27, 131–151. doi: 10.1177/1354067X20957549

Timpka, T., and Nyce, J. M. (2021). Face mask use during the COVID-19 pandemic the significance of culture and the symbolic meaning of behavior. *Ann. Epidemiol.* 59, 1–4. doi: 10.1016/j.annepidem.2021.03.012

Tso, I. F., Mui, M. L., Taylor, S. F., and Deldin, P. J. (2012). Eye-contact perception in schizophrenia: Relationship with symptoms and socioemotional functioning. *J. Abnorm. Psychol.* 121, 616–627. doi: 10.1037/a0026596

Wastler, H. M., and Lenzenweger, M. F. (2018). Cone of gaze in positive schizotypy: Relationship to referential thinking and social functioning. *Personal. Disord.* 9, 324–332. doi: 10.1037/per0000258

Zung, W. W., Richards, C. B., and Short, M. J. (1965). Self-rating depression scale in an outpatient clinic. Further validation of the SDS. *Arch. Gen. Psychiatry* 13:508. doi: 10.1001/archpsyc.1965.01730060026004

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Face masks have a limited effect on the feeling of being looked at

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Introduction: Wearing face masks has been promoted as an effective measure to reduce the spread of COVID-19. Because face masks cover a major part of the face, they have detrimental effects on various aspects of social cognition. Yet, a highly important feature of the face is not occluded by face masks: the eyes. The eyes play an important role in social interactions: knowing where another person is looking is of central importance when interacting with others. Recent research has reported an attentional shift toward the eye region as a consequence of the widespread exposure to face masks. However, no study has yet investigated the influence of face masks on the perception of eye gaze direction. Here we investigated whether face masks have an effect on the feeling of being looked at. Assuming an attentional shift toward the eyes, we might expect more accurate gaze perception in faces wearing face masks.

Methods: Sixty-five participants decided for a series of realistic avatar faces whether each face was making eye contact or not. Half of the faces wore face masks, the other half did not. For each participant and separately for each condition (mask vs. no mask), we calculated the cone of direct gaze (CoDG), a commonly used measure to quantify the range of gaze angles within which an observer assumes mutual gaze.

Results: Contrary to our expectations, results show that mutual gaze is not recognized more accurately in masked faces. Rather, the CoDG was, on average, slightly wider for faces wearing masks compared to faces without masks.

Discussion: Notwithstanding the relatively small effect of face mask, these findings potentially have implications on our social interactions. If we inadvertently feel looked at by an onlooker, we may react inappropriately by reciprocating the alleged approach orientation.

KEYWORDS
cone of direct gaze, CoDG, hygienic face mask, eye gaze, mutual gaze

Introduction

Knowing where another person is looking is of central importance for social interactions (Argyle and Cook, 1976; Kleinke, 1986; Baron-Cohen, 1995) since the direction of eye gaze portrays information about other people's focus of attention. Of special importance is the skill to distinguish between mutual and averted eye gaze. When someone looks us in the eye, we may be invited to reciprocate the affiliative orientation, which increases the chance of a social interaction.

The eyes are the most salient and perhaps the biologically most relevant features of a face. Already newborn infants show a preference for the eye region (Farroni et al., 2002) and already at the age of 4 months babies can discriminate between direct and averted gaze (Farroni et al., 2004). It is therefore unsurprising that humans are good at distinguishing between gaze that is averted and mutual gaze (e.g., Gibson and Pick, 1963; Cline, 1967; Gale and Monk, 2000). Despite this generally accurate ability to detect eye contact, various research has demonstrated a considerable range of gaze directions which are perceived as being direct (Gamer and Hecht, 2007; Harbort et al., 2017; Balsdon and Clifford, 2018). Gamer and Hecht (2007) hence suggested using the metaphor of a cone to describe the perception of gaze direction, rather than that of a ray as assumed in earlier studies (e.g., Gale and Monk, 2000; Symons et al., 2004).

The cone of direct gaze (CoDG) describes the range of gaze angles which an observer perceives as making eye contact. Previous research has shown that most people have a rather wide CoDG, meaning they interpret a rather large range of gaze angles as being direct. By accepting a relatively large range of gaze directions to be making eye contact, observers avoid the cost of missing direct gaze, which is greater that mistakenly interpreting averted gaze as direct (Langton et al., 2004).

Since the outbreak COVID-19 pandemic, governments and health authorities around the globe recommend wearing hygienic face masks as an effective measure to reduce the spread of the disease. Because hygienic face masks cover a major part of the face, they substantially impair face perception (Freud et al., 2020; Marini et al., 2021; Noyes et al., 2021) and emotion recognition (Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Noyes et al., 2021; Grahlow et al., 2022). Similarly, Fitousi et al. (2021) found that masks hindered the perception of face identity, emotional expression, age and gender of a face, both in terms of accuracy and speed. The difficulty to correctly "read" faces as a result of face covering leads to detrimental effects on various aspects of social cognition, such as establishing and maintaining effective interpersonal social interactions (Mheidly et al., 2020; Spitzer, 2020). Specifically, wearing face masks affects inter-personal distance regulation (e.g., Cartaud et al., 2020; Kroczek et al., 2022) and the perceived trustworthiness of others (e.g., Oldmeadow and Koch, 2021). However, it seems that people have accustomed to the fact that half the face is covered by a mask. Mheidly et al. (2020) assume that as a consequence of the wide use of face masks in recent years, the visible eye region becomes more important. This was confirmed by recent work of Barrick et al. (2021), who demonstrated that people with higher levels of mask exposure make more use of cues from the eye region when processing emotional facial expressions than people with less mask exposure. Further, as exposure to masks increased, those with the most social interactions also experienced the greatest increase in the use of information from the eye region (Barrick et al., 2021). These results provide evidence that the perception of facial cues shows a certain plasticity. As a consequence of the widespread exposure to face masks, an attentional shift has occurred in how people process faces: they have learnt to direct their attention more to the eye area of the face. It seems evident that during the COVID-19 epidemic a change has occurred in the way we perceive and interpret faces, through the interaction with mask-wearing counterparts.

Given that the recommendation to wear face masks during the COVID-19 pandemic poses challenges on our non-verbal communication, we investigated whether face masks have an effect on the perception of mutual gaze. We use the term "mutual gaze" to describe the situation in which somebody is making eye contact with an observer without distinguishing between gaze and head direction. Following this definition, gaze direction was always aligned with the head orientation in the present study and the head as a whole was rotated (cf. Gianotti et al., 2018; Lobmaier et al., 2021). We measured the CoDG to quantify the range of gaze angles within which an observer assumes mutual gaze (cf. Gamer and Hecht, 2007; Ewbank et al., 2009; Gamer et al., 2011; Harbort et al., 2017; Gianotti et al., 2018). Because people will resort to information contained in the visible eye region when the lower part of the face is covered, we expect the CoDG to be narrower (i.e., perception of mutual gaze to be more accurate) in faces wearing hygienic masks. By covering other prominent facial parts (e.g., mouth, cheeks, and nose), face masks may result in less distraction from the eyes or might generally make the eyes more salient, again leading to more accurate gaze perception. Because the alleged attentional shift toward the eye region seems to depend on the amount of exposure to face masks in everyday life (cf. Barrick et al., 2021), we also assessed and controlled for the amount of exposure to face masks using the questionnaire introduced by Barrick et al. (2021).

Materials and methods

Participants

Sixty-five participants (17 men, 48 women) aged between 19 and 29 years (M = 22.9, SD = 2.4) volunteered to take part in this study for course credit or a snack. All participants had normal or corrected to normal vision. Sixty participants were of Caucasian decent, five were of other ethnicities (Asian, African, or South-American). All participants reported that they lived and were brought up in Central Europe. In three cases the CoDG could not be estimated due to inconsistent responses recorded during the task (two in the "mask" condition and one in the "no mask" condition). The study was approved by the local Ethics Committee. All participants gave written informed consent and were informed of their right to discontinue participation at any time. Data were collected in a single wave and then analyzed (no analyses were calculated before all participants were tested).

Stimuli

Three-dimensional face stimuli were created using the software package FaceGen Modeller 3.5.2 (Singular Inversions Inc., 2010) which enables the generation of face stimuli with a high level of realism. Faces of four Caucasian gender-neutral avatars showing a neutral expression were generated (FOV Angle = 17; Distance Ratio = 3). To ensure that the perceptual features of different face stimuli did not affect the results, the four avatars were generated by using the "genetic" tool. This tool allows to create highly similar faces with a predefined level of randomness (30%). The gaze direction of the faces was aligned with the head direction, so that nose and gaze fixation point lay on the same axis. The avatar heads obtained with this procedure were then rotated in 1° steps producing 17 different viewing angles (from 1° to 8° to the left and right, and 0°). For the "facemask" condition, a surgical face mask was superimposed on each avatar face using Adobe Photoshop 2021.

Task and procedure

After obtaining written informed consent, participants were seated comfortably in a dimly lit room and received written instructions for the gaze discrimination task. They sat a distance of approximately 60 cm from a PC screen. The face stimuli appeared on the screen with a width of 6 cm, thus subtending a visual angle of approximately 5.7°. This corresponds to a distance of approximately 180 cm in real life. Lighting conditions were kept constant for all participants and the screen position was manually adapted so that the eyes of the avatars were vertically aligned with the eyes of the participants. We used an established gaze perception paradigm (cf. Gianotti et al., 2018; Lobmaier et al., 2021) where each participant saw a series of avatar faces and decided for each face whether it was making eye contact or not. Half of the avatar faces wore face masks, the other half did not. Each trial started with the presentation of a fixation cross for a variable duration (between 750 and 900 ms) followed by a stimulus face (300 ms). After this, participants had 1,700 ms to answer. Participants were asked to decide as quickly as possible whether the presented face was gazing directly at them using predefined buttons on a custom made response box. A schematic timeline of the gaze discrimination task is shown in **Figure 1**. The keys on the response box were aligned perpendicular to each other to avoid any gaze induced response biases. The correspondence between yes/no keys and which hand was used for yes/no was counterbalanced across participants. The gaze discrimination task comprised 288 trials [18 angles (0° angle was shown

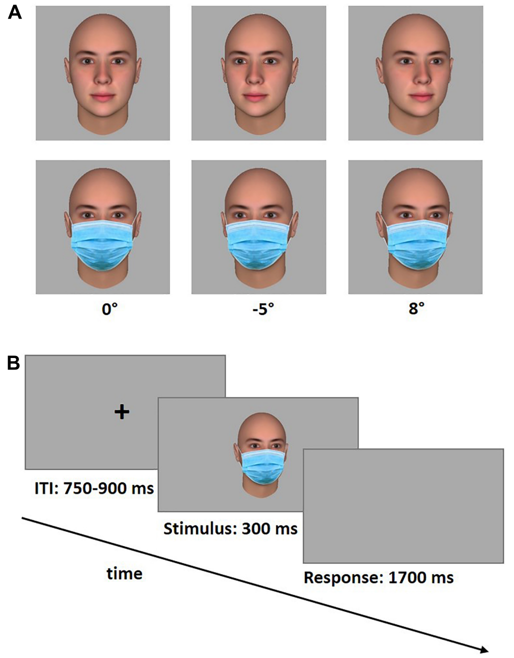

FIGURE 1
Stimulus examples in three different viewing angles (0°, −5°, and 8°), with and without face mask **(A)** and schematic time line of the gaze task **(B)**. The task consisted of a variable inter-stimulus interval (ITI), followed by a stimulus face (300 ms), which was then replaced with a response window (1,700 ms). Participants responded whether or not the stimulus face was looking at them *via* two orthogonally arranged custom-made response buttons.

twice) × 4 avatars × 2 repetitions × 2 experimental conditions (mask vs. no mask)]. Masked and unmasked stimuli were presented blockwise in an ABABAB/BABABA fashion where A is the "no mask" condition and B is the "facemask" condition. Half of the participants started with the "no mask" condition, the other half with the "facemask" condition. Each block contained 48 trials which were presented pseudorandomly within each block, with the constraint that each angle and face identity was equally distributed across the blocks.

After the gaze task which took approximately 15–20 min to complete, participants filled in the questionnaire introduced by Barrick et al. (2021) assessing the amount of exposure to face masks during the pandemic.

Statistical analyses

Cone of direct gaze calculation

The proportion of yes and no responses across visual angles were used to compute the CoDG. In a first step we calculated the percentage of times the participant decided that the face stimulus was looking directly at him/her as a function of the gaze angle, separately for each mask condition. Using R statistics software (R Core Team, 2021), we then fitted the data to a logistic function to calculate the points of subjective equivalence (PSE). PSE is defined as the angle at which a participant would be predicted to assume eye contact or no eye contact with equal frequency (i.e., 50%). We calculated the PSE separately for faces rotated to the left and right. The CoDG was calculated as the sum of the absolute values of the left and right side PSE.

Testing the effect of face masks on the cone of direct gaze

Any outliers were winsorized before further analyses (Dixon, 1960). Specifically, outliers more than three standard deviations from the mean were substituted with the highest observed value that was within three standard deviations. This was the case for one data point in the mask condition and one in the no-mask condition.

Linear mixed models (LMM) were run using the R package lme4 (Bates et al., 2015), while the package lmerTest (Kuznetsova et al., 2017) was used to determine the significance of the predictors. LMMs are advantageous over ANOVAs when the data-set is unbalanced or when there are missing values. After calculating the intraclass correlation, to check the adequacy of an LMM, a random-intercept model was estimated. In this model, only the level 1 predictor "condition" was included in the model as a fixed effect, with CoDG as the dependent variable and a random intercept for participants. As suggested by LaHuis et al. (2014), the explained variance (R2) by condition was calculated using this random intercept model. In a second step, we additionally entered the predictors participant sex and amount of exposure (full model).

Results

In the mask condition, the CoDG ranged from 1.84° to 9.59° (mean = 5.58°), in the no-mask condition, the CoDG ranged from 0.48° to 9.57° (mean = 5.19°) (see **Figure 2**). The intraclass correlation of 0.86 revealed substantial differences in CoDG between participants. Regarding the fixed effect, the results of the LMM with CoDG as the dependent variable and the mask condition as the predictor revealed a main effect of mask condition (estimate = −0.280; standard error = 0.126; 95% CI [−0.53, −0.03]; $t = -2.229$, df = 60.89; $p = -0.03$). Therefore, on average, the CoDG for faces without masks were 0.28 degrees narrower than for faces with a mask. The predictor condition explained approximately 5.2% of the level-1 variance within individuals of CoDG. The full model with CoDG as the dependent variable and mask condition, participant sex and exposure as predictors, and participant as random factor again revealed a significant effect of mask condition ($p = -0.030$), but no effect of participant sex ($p = -0.821$) and no effect of amount of exposure to face masks ($p = -0.179$; see **Table 1**). This full model explained 5.4% of the variance, only slightly more than condition alone.

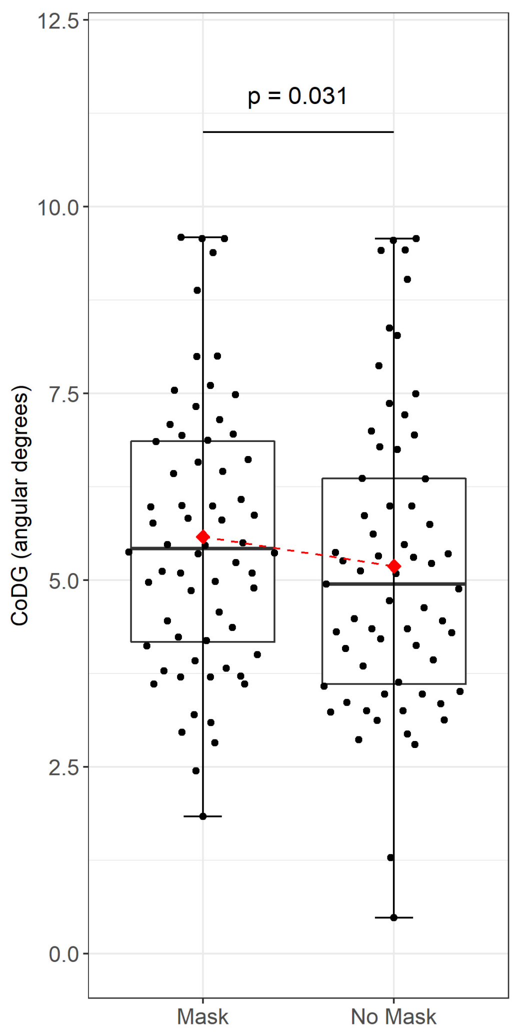

FIGURE 2
Data are plotted as box plots for each condition ("mask" and "no mask"). Bold horizontal lines indicate median values, boxes indicate 25/75% interquartile range, and whiskers indicate 1.5 × interquartile range. Red diamonds indicate the mean cone of direct gaze (CoDG) in the "mask" and "no mask" condition. Red line connects mean CoDG in "mask" and "no mask" condition. Individual CoDG are shown separately as black dots, jittered proportionally to the density (jittered density plot).

Discussion

The use of hygienic face masks pose challenges on our social interactions because they cover a major part of the face. In the present study, we investigated whether face masks have an effect on the interpretation of mutual eye gaze. Because facemasks cover the lower part of the face but spare information contained in the eye region, we assumed that, when looking at faces wearing hygienic masks, people would resort more strongly to the eyes than when the whole face is visible, leading to more accurate gaze perception. Contrary to our expectations, this was not the case: our results indicate a small but significant widening

TABLE 1 Fixed effects parameter estimates.

Effect	Estimate	SE	95% Confidence interval Lower	Upper	df	t	p
(Intercept)	4.40	0.90	4.95	5.86	62.50	4.87	<0.001
Condition (No mask–mask)	−0.28	0.13	−0.53	−0.03	61.03	−2.22	**0.030**
Part sex (male–female)	−0.12	0.53	−1.29	1.25	62.29	−0.28	0.821
Exposure to face masks	0.00	0.00	0.00	0.01	61.76	1.36	0.179
Condition × exposure	0.00	0.00	0.00	0.00	60.10	−0.34	0.734

Estimate, unstandardised regression coefficients; SE, standard error; df, degree of freedom. Significant p-value for Condition in bold type.

of the CoDG for faces with masks compared to faces without masks. On average, in the mask condition, people more often assumed mutual gaze when the faces were actually averted than in the no-mask condition. Closer inspection of the data revealed that this was the case for 61% of participants, whereas for 39% of the participants the CoDG got narrower in the mask condition. So, even though the mask effect is statistically significant, it did not occur for all participants and the overall effect is relatively small: the mask condition explained approximately 5.2% of the variance only. Moreover, the amount of exposure to face masks in everyday life did not influence the CoDG, neither in the mask nor in the no-mask condition, suggesting that people with higher levels of mask exposure do not make more use of cues from the eye region when processing eye gaze than people with less mask exposure.

Our findings suggest that the alleged attention shift toward the eye region as a result of high exposure to face masks had only limited effect on the CoDG. This finding is somewhat in line with a recent study by Dalmaso et al. (2021), who explored the potential impact of face masks on gaze induced attentional shifts. Using a gaze cueing paradigm in which the centrally presented cue either was a face wearing a hygienic face mask or a face without a mask, they found that face masks had no impact on cueing of attention. But even if attention were drawn to the eyes, a predominant uncertainty remains when encountering a person wearing a mask. Wearing masks increases the ambiguity of social interactions and this naturally leads to even more uncertainty. This increased uncertainty may also make it more difficult to interpret gaze direction. As a result, people may tend to interpret ambiguous gaze lines as making eye contact. Indeed, previous research indicates that as ambiguity increases, gaze is more likely to be judged as directed toward oneself (Mareschal et al., 2013; Balsdon and Clifford, 2018). A different study found that stressed people tend to interpret a wider range of gaze lines as making eye contact than unstressed people (Rimmele and Lobmaier, 2012). This interpretation is consistent with the evolutionary informed view that in cases of ambiguity or heightened stress, it is safer to assume eye contact when the looker is actually averting her gaze than to mistakenly interpret direct gaze as being averted (Langton et al., 2004).

Wearing face masks seems to induce an additional bias on the perception of mutual gaze (at least in most people), making it more likely to experience mutual gaze. This may be because the mask disguises other important cues to gaze direction, such as the direction of the nose and mouth (cf. Langton et al., 2004). Alternatively, the widened CoDG for faces wearing hygienic masks could be due to the fact that social interactions with mask-wearing individuals are generally more challenging due to impaired face recognition (Freud et al., 2020; Marini et al., 2021; Noyes et al., 2021) and impaired emotion recognition (Carbon, 2020; Grundmann et al., 2021; Marini et al., 2021; Noyes et al., 2021; Grahlow et al., 2022).

Finally, a further possible explanation for wider CoDG in masked faces is that hygienic masks alter perceived attractiveness of a face. Indeed, recent research found that faces wearing face masks are perceived as being more attractive than uncovered faces (Patel et al., 2020; Hies and Lewis, 2022). Meanwhile, gaze lines of more attractive people are more often interpreted as making eye contact than gaze lines of less attractive people, presumably due to a self-referential positivity bias (Kloth et al., 2011). So, if hygienic masks increase the attractiveness of a face and if the CoDG is wider when interpreting the gaze of an attractive compared to a less attractive face, it stands to reason that the CoDG should be wider when interacting with a person wearing a face mask. To specifically test whether the avatar faces used in the present study appear to be more attractive when wearing face masks, we conducted a follow-up study, in which 64 additional participants rated the attractiveness of each of the four avatar faces once with and once without a face mask. Faces were presented one after the other in a random order and participants used a slider to rate the attractiveness of each face on a scale ranging from 0 (very unattractive) to 100 (very attractive). Results unequivocally showed that masked faces were perceived as being more attractive (M = 53.5) than faces without masks (45.9), $t = 3.83$, $p < 0.001$, thus replicating previous findings (Patel et al., 2020; Hies and Lewis, 2022). More importantly, assuming that more attractive faces are more likely interpreted as making eye contact than less attractive faces (Kloth et al., 2011) the findings of the follow-up study can be taken as an indirect explanation for the slightly wider CoDG in the mask condition compared to the no-mask condition.

We note that our claims have to be treated with some caution. As mentioned above, even though the CoDG was significantly wider for faces wearing hygienic masks, the presence of face masks explained only a small proportion of the variance. This indicates that further factors contribute to the variability in the width of the CoDG. It will have to be the aim of future studies to identify these. A second noteworthy limitation is that in this study we use the term "mutual gaze" to describe the situation in which somebody is making eye contact with an observer without distinguishing between gaze and head direction (cf., Gianotti et al., 2018; Lobmaier et al., 2021). Although people certainly sometimes avert their gaze while orienting their head straight ahead, we followed the assumption that people will most likely also turn their heads toward the person they are communicating with. Thus, we varied gaze direction together with the head direction to create what we believed to be an ecologically valid situation. With this definition it is difficult to know whether the observed results are relative to a variation in the gaze direction alone or to a variation in the direction of the whole head. Because gaze direction and head orientation were aligned, facial masks may have occluded convergent information regarding the exact gaze direction, particularly the orientation of the nose. Also, our assumption that eye direction and head orientation largely coincide does not accommodate the fact that slight deviations of gaze and head direction are likely to occur in real life. Indeed, smaller corrections of the gaze direction take place without head movements. Whether and how such misalignments of gaze and head direction can influence the CoDG in masked faces is a highly interesting question that deserves further investigation. The idea that increased attention to the eye region improves accuracy of gaze perception might come into play especially when eyes and head direction are not aligned, because only then the complex interactions between head orientation and gaze direction on perceived gaze direction arise (Hecht et al., 2020, 2021). Future studies may wish to specifically disentangle the relative influence of head and eye direction.

The use of hygienic face masks is expected to continue to be part of normality even after the COVID-19 pandemic (Rab et al., 2020; Molnar-Szakacs et al., 2021), hence evidence-based research is needed that investigates the impact of mask wearing on our social interactions. While numerous studies have investigated how mask wearing affects perception of emotional facial expressions or face recognition, we are aware of no study that studied interpretation of eye gaze direction in faces wearing face masks. The present study contributes to reducing this research gap by examining whether wearing a face mask affects the feeling of being looked at. Using an established paradigm to measure the CoDG (cf., Gianotti et al., 2018; Lobmaier et al., 2021), we found that, on average, the CoDG was slightly wider when judging the gaze direction of faces with hygienic masks. This means that, at least for the majority of people, face masks can lead to biased perception of mutual eye gaze in a way that we more likely feel looked at by mask-wearers than by people without face masks. As noted above, the mask effects were rather small, suggesting that overall, the neural mechanisms responsible for detecting mutual gaze are surprisingly robust and are only minimally disrupted when half of the face is covered by a hygienic mask. Nevertheless, in our everyday lives, face masks can have an impact on our social interactions in a way that, if we inadvertently feel looked at and addressed by an onlooker, we may react inappropriately by reciprocating the alleged approach orientation.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committe of the Faculty of Human Sciences, University of Bern. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JL performed the statistical analysis and wrote the first draft of the manuscript. JL and DK contributed to conception, design of the study, manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Argyle, M., and Cook, M. (1976). *Gaze and mutual gaze*. New York, NY: Cambridge University Press.

Balsdon, T., and Clifford, C. W. G. (2018). How wide is the cone of direct gaze? *R. Soc. Open Sci.* 5:180249. doi: 10.1098/rsos.180249

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: The MIT Press.

Barrick, E. M., Thornton, M. A., and Tamir, D. I. (2021). Mask exposure during COVID-19 changes emotional face processing. *PLoS One* 16:e0258470. doi: 10.1371/journal.pone.0258470

Bates, D., Machler, M., Bolker, B. M., and Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. doi: 10.18637/jss.v067.i01

Carbon, C. C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Cartaud, A., Quesque, F., and Coello, Y. (2020). Wearing a face mask against Covid-19 results in a reduction of social distancing. *PLoS One* 15:e0243023. doi: 10.1371/journal.pone.0243023

Cline, M. G. (1967). The perception of where a person is looking. *Am. J. Psychol.* 80, 41–50.

Dalmaso, M., Zhang, X. Y., Galfano, G., and Castelli, L. (2021). Face masks do not alter gaze cueing of attention: Evidence from the COVID-19 pandemic. *Iperception* 12:20416695211058480. doi: 10.1177/20416695211058480

Dixon, W. J. (1960). Simplified estimation from censored normal samples. *Ann. Math. Stat.* 31, 385–391. doi: 10.1081/BIP-200035462

Ewbank, M. P., Jennings, C., and Calder, A. J. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *J. Vis.* 9, 16.1–16.7. doi: 10.1167/9.12.16

Farroni, T., Csibra, G., Simion, F., and Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proc. Natl. Acad. Sci. U.S.A.* 99, 9602–9605.

Farroni, T., Johnson, M. H., and Csibra, G. (2004). Mechanisms of eye gaze perception during infancy. *J. Cogn. Neurosci.* 16, 1320–1326.

Fitousi, D., Rotschild, N., Pnini, C., and Azizi, O. (2021). Understanding the impact of face masks on the processing of facial identity, emotion, age, and gender. *Front. Psychol.* 12:743793. doi: 10.3389/fpsyg.2021.743793

Freud, E., Stajduhar, A., Rosenbaum, R. S., Avidan, G., and Ganel, T. (2020). The COVID-19 pandemic masks the way people perceive faces. *Sci. Rep.* 10:22344. doi: 10.1038/s41598-020-78986-9

Gale, C., and Monk, A. F. (2000). Where am i looking? The accuracy of video-mediated gaze awareness. *Percept. Psychophys.* 62, 586–595. doi: 10.3758/bf03212110

Gamer, M., and Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *J. Exp. Psychol. Hum. Percept. Perform.* 33, 705–715. doi: 10.1037/0096-1523.33.3.705

Gamer, M., Hecht, H., Seipp, N., and Hiller, W. (2011). Who is looking at me? The cone of gaze widens in social phobia. *Cogn. Emot.* 25, 756–764. doi: 10.1080/02699931.2010.503117

Gianotti, L. R. R., Lobmaier, J. S., Calluso, C., Dahinden, F. M., and Knoch, D. (2018). Theta resting EEG in TPJ/pSTS is associated with individual differences in the feeling of being looked at. *Soc. Cogn. Affect. Neurosci.* 13, 216–223. doi: 10.1093/scan/nsx143

Gibson, J. J., and Pick, A. D. (1963). Perception of another person's looking behavior. *Am. J. Psychol.* 76, 386–394.

Grahlow, M., Rupp, C. I., and Derntl, B. (2022). The impact of face masks on emotion recognition performance and perception of threat. *PLoS One* 17:e0262840. doi: 10.1371/journal.pone.0262840

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Harbort, J., Spiegel, J., Wittöft, M., and Hecht, H. (2017). The effects of social pressure and emotional expression on the cone of gaze in patients with social anxiety disorder. *J. Behav. Ther. Exp. Psychiatry* 55, 16–24. doi: 10.1016/j.jbtep.2016.11.004

Hecht, H., Siebrand, S., and Thones, S. (2020). Quantifying the Wollaston Illusion. *Perception* 49, 588–599. doi: 10.1177/0301006620915421

Hecht, H., Wilhelm, A., and von Castell, C. (2021). Inverting the Wollaston illusion: Gaze direction attracts perceived head orientation. *Iperception* 12, 1–13. doi: 10.1177/20416695211046975

Hies, O., and Lewis, M. B. (2022). Beyond the beauty of occlusion: Medical masks increase facial attractiveness more than other face coverings. *Cogn. Res. Princ. Implic.* 7:1. doi: 10.1186/s41235-021-00351-9

Kleinke, C. L. (1986). Gaze and eye contact: A research review. *Psychol. Bull.* 100, 78–100.

Kloth, N., Altmann, C. S., and Schweinberger, S. R. (2011). Facial attractiveness biases the perception of eye contact. *Q. J. Exp. Psychol.* 64, 1906–1918. doi: 10.1080/17470218.2011.587254

Kroczek, L. O. H., Bohme, S., and Muhlberger, A. (2022). Face masks reduce interpersonal distance in virtual reality. *Sci. Rep.* 12:2213. doi: 10.1038/s41598-022-06086-x

Kuznetsova, A., Brockhoff, P. B., and Christensen, R. H. B. (2017). lmerTest package: Tests in linear mixed effects models. *J. Stat. Softw.* 82, 1–26.

LaHuis, D. M., Hartman, M. J., Hakoyama, S., and Clark, P. C. (2014). Explained variance measures for multilevel models. *Organ. Res. Methods* 17, 433–451. doi: 10.1177/1094428114541701

Langton, S. R., Honeyman, H., and Tessler, E. (2004). The influence of head contour and nose angle on the perception of eye-gaze direction. *Percept. Psychophys.* 66, 752–771. doi: 10.3758/bf03194970

Lobmaier, J. S., Savic, B., Baumgartner, T., and Knoch, D. (2021). The cone of direct gaze: A stable trait. *Front. Psychol.* 12:682395. doi: 10.3389/fpsyg.2021.682395

Mareschal, I., Calder, A. J., Dadds, M. R., and Clifford, C. W. (2013). Gaze categorization under uncertainty: Psychophysics and modeling. *J. Vis.* 13:18.

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Mheidly, N., Fares, M. Y., Zalzale, H., and Fares, J. (2020). Effect of face masks on interpersonal communication during the COVID-19 pandemic. *Front. Public Health* 8:582191. doi: 10.3389/fpubh.2020.582191

Molnar-Szakacs, I., Uddin, L. Q., and Heffernan, M. B. (2021). The face behind the mask: The future of interpersonal interaction. *Neuron* 109, 1918–1920. doi: 10.1016/j.neuron.2021.05.030

Noyes, E., Davis, J. P., Petrov, N., Gray, K. L. H., and Ritchie, K. L. (2021). The effect of face masks and sunglasses on identity and expression recognition with super-recognizers and typical observers. *R. Soc. Open Sci.* 8:201169. doi: 10.1098/rsos.201169

Oldmeadow, J. A., and Koch, C. (2021). Effects of face masks on person perception. *Perception* 50, 876–889. doi: 10.1177/03010066211045172

Patel, V., Mazzaferro, D. M., Sarwer, D. B., and Bartlett, S. P. (2020). Beauty and the mask. *Plast. Reconstr. Surg. Glob. Open* 8:e3048. doi: 10.1097/GOX.0000000000003048

R Core Team (2021). *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. Available online at: https://www.R-project.org/

Rab, S., Javaid, M., Haleem, A., and Vaishya, R. (2020). Face masks are new normal after COVID-19 pandemic. *Diabetes Metab. Syndr.* 14, 1617–1619. doi: 10.1016/j.dsx.2020.08.021

Rimmele, U., and Lobmaier, J. S. (2012). Stress increases the feeling of being looked at. *Psychoneuroendocrinology* 37, 292–298. doi: 10.1016/j.psyneuen.2011.06.013

Spitzer, M. (2020). Masked education? The benefits and burdens of wearing face masks in schools during the current Corona pandemic. *Trends Neurosci. Educ.* 20:100138. doi: 10.1016/j.tine.2020.100138

Symons, L. A., Lee, K., Cedrone, C. C., and Nishimura, M. (2004). What are you looking at? Acuity for triadic eye gaze. *J. Gen. Psychol.* 131, 451–469.

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The role of face masks within in-patient psychotherapy: Results of a survey among inpatients and healthcare professionals

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Introduction: Face-to-face medical and psychotherapeutic treatments during the Corona pandemic often involve patients and health care providers wearing face masks. We performed a pilot survey assessing the subjective experience of wearing face masks during psychotherapy sessions regarding (i) feasibility, (ii) psychotherapeutic treatment and (iii) communication, emotion and working alliance in patients and healthcare professionals.

Methods: A total of n = 62 inpatients (RR = 95.4%) and n = 33 healthcare professionals (RR = 86.8%) at an academic department of Psychosomatic Medicine and Psychotherapy participated in this survey anonymously. The items of the questionnaire were created by the interprofessional expert team and were based on existing instruments: (i) the Therapeutic Relationship Questionnaire and (ii) the German translation of Yalom's Questionnaire on Experiencing in Group Psychotherapy.

Results: The majority of patients rate their psychotherapy as highly profitable despite the mask. In individual therapy, face masks seem to have a rather low impact on subjective experience of psychotherapy and the relationship to the psychotherapist. Most patients reported using alternative facial expressions and expressions. In the interactional group therapy, masks were rather hindering. On the healthcare professional side, there were more frequent negative associations of face masks in relation to (i) experiencing connectedness with colleagues, (ii) forming relationships, and (iii) therapeutic treatment.

Discussion: Information should be given to patients about the possible effects of face masks on the recognition of emotions, possible misinterpretations and compensation possibilities through alternative stimuli (e.g., eye area) and they should be encouraged to ask for further information. Especially in group therapy, with patients from other cultural backgrounds and in cases of need for help (e.g., hearing impairment) or complex disorders, appropriate non-verbal gestures and body language should be used to match the intended emotional expression.

KEYWORDS

face masks, inpatient, psychotherapy, healthcare professionals, COVID-19, in-patient psychotherapy

Introduction

The global COVID-19 pandemic challenges the healthcare system on multiple fronts and has profound effects on the daily lives of people worldwide (Brooks et al., 2020; Mazza et al., 2020; Pierce et al., 2020). Meta-analyses (Vindegaard and Benros, 2020; Busch et al., 2021; Danet, 2021; Dragioti et al., 2022) show a significant increase in mental distress among healthcare professionals (Mulfinger et al., 2020; Salazar de Pablo et al., 2020; Jones et al., 2021) in addition to the significantly increased prevalence of mental distress in general (Xiong et al., 2020; Santomauro et al., 2021). Alongside the medical care of SARS-CoV-2 patients, the continued treatment of all other patients must also be ensured. The pandemic has also led to changes in the provision of psychotherapeutic services: while psychotherapy has partly been conducted using telephone or videoconferencing throughout the pandemic, face-to-face psychotherapy continued to be offered, especially for severely ill patients in day-patient and inpatient settings (Zipfel et al., 2020).

Among many benefits of telemedicine and telepsychotherapy (Poletti et al., 2021; Lin et al., 2022) challenges remain, such as a "lack of control over the patient's environment," reduced privacy and confidentiality, and possibly limited assessment of treatment progress and difficulties in establishing a therapeutic relationship without face-to-face contact (Cataldo et al., 2021; Mitzkovitz et al., 2022).

Face-to-face psychotherapy has changed in many ways: smaller group sizes, a distance of at least 1.5–2 m, and refrain from physical contact, healthcare professionals, and patients wear face masks in multiple medical and therapeutic contexts. Face masks cover/conceal important facial features of non-verbal communication, more specifically the lower part of the face. Between 65 and 90 per cent of human communication is non-verbal, with all communication containing a contextual and a relational aspect, with the latter determining the former (Foley and Gentile, 2010). In general, the contextual aspect has the task of conveying information. The relational aspect provides information about how the relationship is perceived by the receiver. In this context, non-verbal communication is conveyed through body posture, facial expressions, gestures, speech quality, and predispositions, among other things (e.g., Watzlawick, 1969; Foley and Gentile, 2010; Wieser and Brosch, 2012). In the upper half of the face, movements such as lifting and contracting the eyelids and raising and lowering the eyebrows occur, whereas in the lower half of the face (movements such as), pulling the corners of the lips, splitting the lips, and lifting the lips occur. Different emotions are predominantly handled by functional areas of the upper or the lower face. Anger and sadness are more likely to be addressed by lower functional areas, while both halves of the face are relevant for fear and surprise. The loss of information from the lower face through the mask thus increases the ambiguity of a message (Carbon, 2020; Ekman and Rosenberg, 2020; Pavlova and Sokolov, 2021).

Drawing from these findings we were interested in potential side-effects of wearing face-masks on the therapeutic relationship. The therapeutic alliance is a key factor for positive treatment outcomes (Flückiger et al., 2018). On the one hand, masks carry the risk of misrecognizing facial expressions, especially if the expression does not match the corresponding body language. This is particularly relevant for patient groups for whom emotion recognition is a problem, or who are more susceptible to emotion recognition bias (e.g., Mitzkovitz et al., 2022). Based on previous research on the perception of masks among individuals suffering from health anxiety (Cannito et al., 2020), an attentional bias toward virus-relevant stimuli (i.e., face masks) and thus interactionally disruptive effects on psychotherapy may be assumed. Similarly, face masks could create unfamiliar distance and impair the feeling of coherence (e.g., Wong et al., 2013). As recent research in the context of the COVID-19 pandemic has shown, there is also a striking influence on the trustworthiness of the interaction partner through the wearing of a mask (Biermann et al., 2021; Malik et al., 2021; Cannito et al., 2022; Marini et al., 2022). As proposed in the concept of epistemic trust (Fonagy and Allison, 2014), basal trust in a reference person as a secure source of information can be perceived as core element of a functioning, resilient therapeutic relationship. This relationship, or rather the successful therapeutic relationship building, may therefore be impaired by the wearing of a mask (Cannito et al., 2022).

However, face masks can create possible opportunities for increased abstinence on the part of the professional and increased problem activation on the part of the patient (Grawe, 1997). Recent research has shown that wearing a mask is not only obstructive. Marini et al. (2022) have shown that wearing a mask may mitigate positive and negative perception biases since visual information underlying trustworthiness is also available in masked faces (Marini et al., 2022). Both can be an opportunity and an overload depending on the current stress, resource activation, problem, and structural level.

The Aim of this study was to explore inpatients and healthcare professionals from a German tertiary hospital in a department of Psychosomatic Medicine and Psychotherapy concerning their subjective perceptions and experience of wearing face masks within psychotherapy during the first wave of COVID-19 outbreak in Germany in regard to three dimensions:

1. general feedback and feasibility;
2. specific psychotherapeutic treatment; and
3. communication, emotion, and relationships with others.

To the best of our knowledge, there has been no similar study on the above-mentioned relationships.

Materials and methods

Material and procedure

The study was conducted in a German tertiary hospital in a department of psychosomatic medicine and psychotherapy using a paper-and-pencil survey. The participant sample included inpatients and healthcare professionals, including psychotherapeutically trained nurses, physicians, psychotherapists, and specialty therapists. Between July and October 2020, $n = 65$ inpatients and $n = 38$ medical healthcare professionals were invited to participate in the survey. Therefore, we invited all patients who were hospitalized during this period, as well as all health professionals involved in therapeutic activities during this period, to participate in the study. Participants were informed about the purpose of the study, the study investigators, and the use of non-personal data by a study information sheet. The paper-pencil questionnaire was completed voluntarily and without any consequences for the participants. The questionnaire was handed out by a scientific research associate (CW), not integrated in psychotherapeutic treatment. Patients received the questionnaire within the first 2 weeks after admission. After completing the anonymous questionnaire, participants could drop the questionnaire into a locked box.

The questionnaire included $n = 60$ (patient version) vs. $n = 92$ (staff version) items concerning experiences and perceptions of wearing face masks in psychotherapy, both on patient and staff side. They were developed by an interprofessional team (psychologists, psychotherapists, clinical scientists, physicians, nurses, and special therapists) and were also inspired by existing validated instruments like the Therapeutic Relationship Questionnaire (Schulte, 1996) and the German translation of Yalom's Questionnaire on Experiencing in Group Psychotherapy (Mander et al., 2016). The Questions were asked dichotomy ["Yes, face mask affects (complicates or encourage) this area/item" or "No, face mask does not affect this area/item"]. Furthermore, free text fields were provided for each domain. **Table 1** shows 10 exemplary items for both groups. Please note that in addition to their subjective experience

TABLE 1 Illustration of ten exemplary items for both groups.

Patient side	**Health professional side**
Face mask complicates/encourages. . . OR face mask does not affect. . .	**Face mask complicates/encourages. . . OR face mask does not affect. . .**
My communication with fellow patients.	My personal wellbeing negatively/positively.
Me feeling understood in my problems by my therapist.	My patients knowing what I expect from them.
My personal therapeutic work with the nursing team.	Talking (consciously) to patients in a more resource-oriented way (such as "auxiliary I," more praise, appreciative language, more validation, clearer language).
Me feeling free to shape the course of therapy.	My patients confiding intimate things to me.
Me approaching the staff for help.	My patients coping well with difficult situations in the group therapy.
Me feeling safe and secure in the group.	The therapeutic work in music or art therapy.
Learning something from other patients in the group sessions (e.g., experiences, perspectives, strategies).	My patients feeling understood by me in their problems.
Addressing many things that are important for me in the individual therapy.	My patients developing positive feelings about their future in the group therapy.
Me feeling valued and/or understood by the other patients in the group therapy sessions.	A lot of uncertainty in the team.
Me feeling that the therapist pays enough attention to my feelings.	My patients feeling important and valuable in the group therapy/individual therapy.

regarding the face masks, the healthcare professionals also gave a rating for the potential effects of face masks on patients. No person-specific information or information on personal data such as gender, age, type of diagnosis, or clinical parameters was obtained.

The responsible ethics committee of the University Hospital and Medical Faculty of the University of Tübingen was informed (project number: 685/2002A). For completely anonymous data, consultation and approval on the collection, analysis, and publication by the ethics committee is not required.

Analysis of data

Statistical analyses were carried out using IBM SPSS for Windows, version 27 (IBM Corp., Armonk, NY, USA). We calculated frequencies for agreeing and disagreeing with a subjectively perceived effect of the mask on each question. Given this data evaluation procedures, no power calculation (*a priori* or *posteriori*) was necessary. The free text responses addressed were analyzed with a thematic content analysis using Microsoft Excel as the coding software (in regard to Braun and Clarke, 2006). Codes and dimensions from the data set were identified, analyzed, and documented. During the content analysis, the reviewers (RE and CW) familiarized themselves with the data and developed codes. Following the search, exploration and specification of the themes, the results of the analysis were interpreted and integrated for both the questionnaire results and the free text fields (RE and SHA). The resulting dimensions were:

(i) general feedback and feasibility;
(ii) psychotherapeutic treatment; and
(iii) communication, emotion, and relationships (including team members, patient–to patient, and patient–healthcare professionals).

Results

A total of 62 inpatients (RR = 95.4%) and 33 healthcare professionals (RR = 86.8%) took part in this survey. Seven patients and five healthcare professionals had to be excluded from the further analysis due to incomplete (>20%) or ambiguous answers. A total of n = 55 patients (84.6%) and 28 healthcare professionals (73.7%) were included finally in the following analyses. **Figure 1** illustrates the qualitative results within the three dimensions by healthcare professionals and patients.

General feedback and feasibility

Over 95% of the respondents (patients and healthcare professionals) reported wearing face masks according to the ward rules. Overall, 68% (n = 19) of healthcare professionals reported difficulty wearing the face mask compared to n = 36 (65.5%) of patients. In total 62% of the healthcare professionals reported gradually getting used to wearing the mask, while only about 40% (n = 22) of the patients managed to do so.

Both groups were concerned that face masks would be detrimental to their health. They stated that face masks emitted unpleasant odors, that the masks led to increased breathing difficulties and panic attacks, and that there was increased sweating and feelings of anxiety and panic (on the part of the patients). On the practitioner's side, it was emphasized that stair climbing was impaired under the mask. A total of 54% (n = 15) of the healthcare professionals stated that the face mask had a negative influence on their own wellbeing. A total of 74% (n = 27) of the healthcare professionals were able to recognize their colleagues "at first sight" even with the mask. On the patient side, n = 43 (79.9%) stated that they could recognize their fellow patients at first sight despite the face masks as well. The majority of patients, n = 45 (84.9%), stated that the face mask did not prevent them from approaching staff (or fellow patients) and asking for help.

Psychotherapeutic treatment

Figure 2 provides information on the direct comparison of patients' and healthcare professionals' ratings of the extent to which face masks have a negative/hindered influence on specific therapies. The percentages refer to the "applicable percentages" of the individual items. The healthcare professionals' individual ratings of the impact of facial masks are consistently more likely to be negative (range 54.2–85.0%) than the patients' ratings (range 11.3–45.1%).

The interfering effect of the face mask varied depending on the respective type of therapy. Face masks were experienced as particularly problematic by patients in "Music therapy or Art therapy" (n = 21, 41.2%), "Relaxation therapy" (n = 23, 45.1%), and individual guidance and therapeutic counseling by nurses with n = 18, 34.6%. For healthcare professionals, the top three therapies in which facial expression was experienced as particularly interfering were "Interactional Group Therapy" and "Body-Related Therapy" with n = 17, 85.0% each, and "Music therapy or Art therapy" (n = 18, 81.8%). Regarding individual therapy, the difference becomes even more apparent. More than 65% of the healthcare professionals estimate a negative influence of face masks in individual psychotherapy. More precisely, 33% of the healthcare professionals thought that the face mask prevented patients from feeling understood by the therapist, or that they did not feel sufficiently listened to (28.6%), or that they are perceived as honest by the patients (29.2%). The majority of healthcare professionals, however, reported not consciously working in a more resource-oriented or less confrontational or exposed way (n = 23; 82%) when wearing the face mask. Methods such as "auxiliary I" (in case of structural

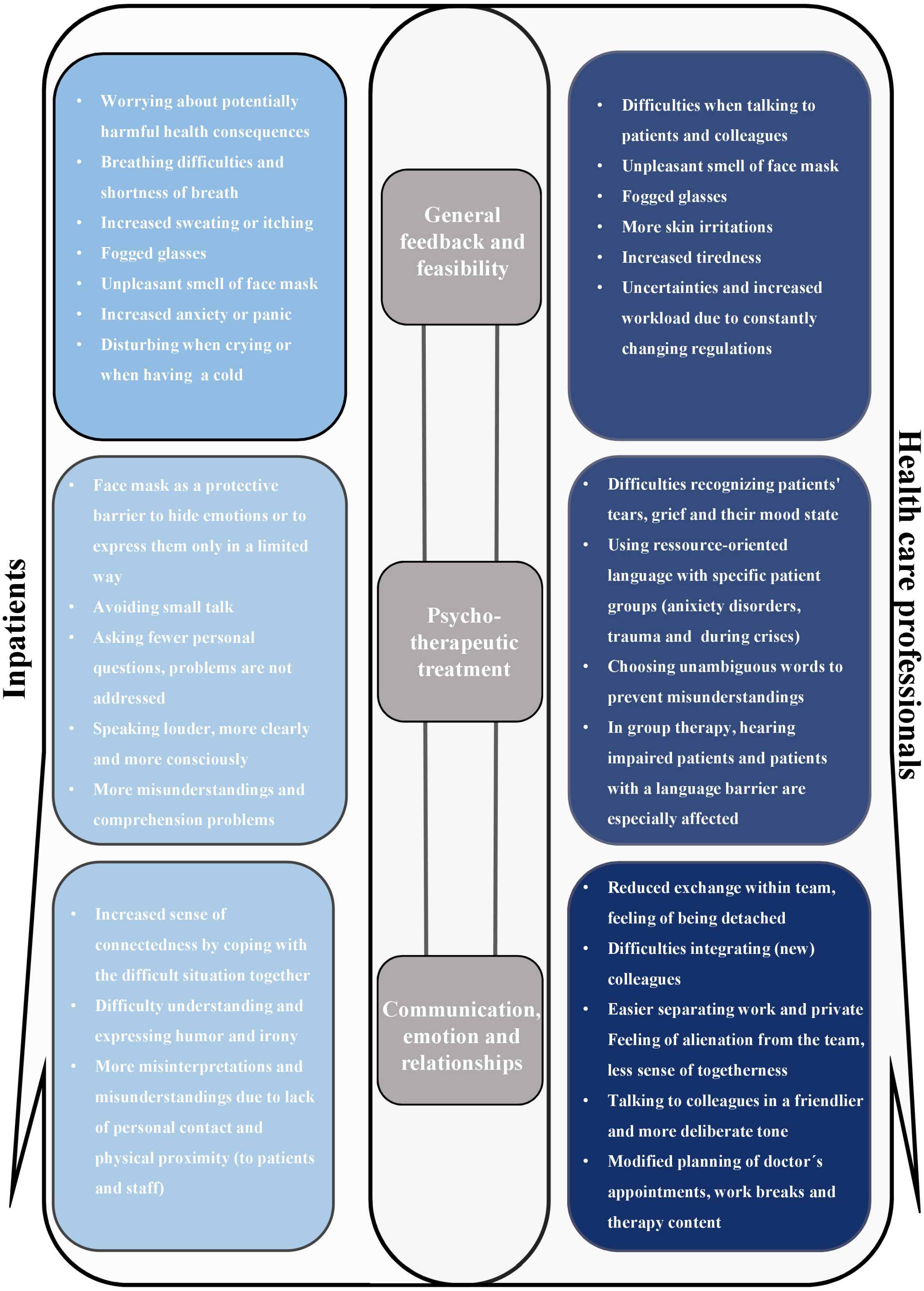

FIGURE 1
Visualization of the qualitative results in the three dimensions (i) General feedback and feasibility, (ii) Psychotherapeutic treatment, and (iii) Communication, emotion, and relationships with others by healthcare professionals **(right)** and patients **(left)**. For each dimension (i–iii), the most frequent statements of the free text fields were compiled.

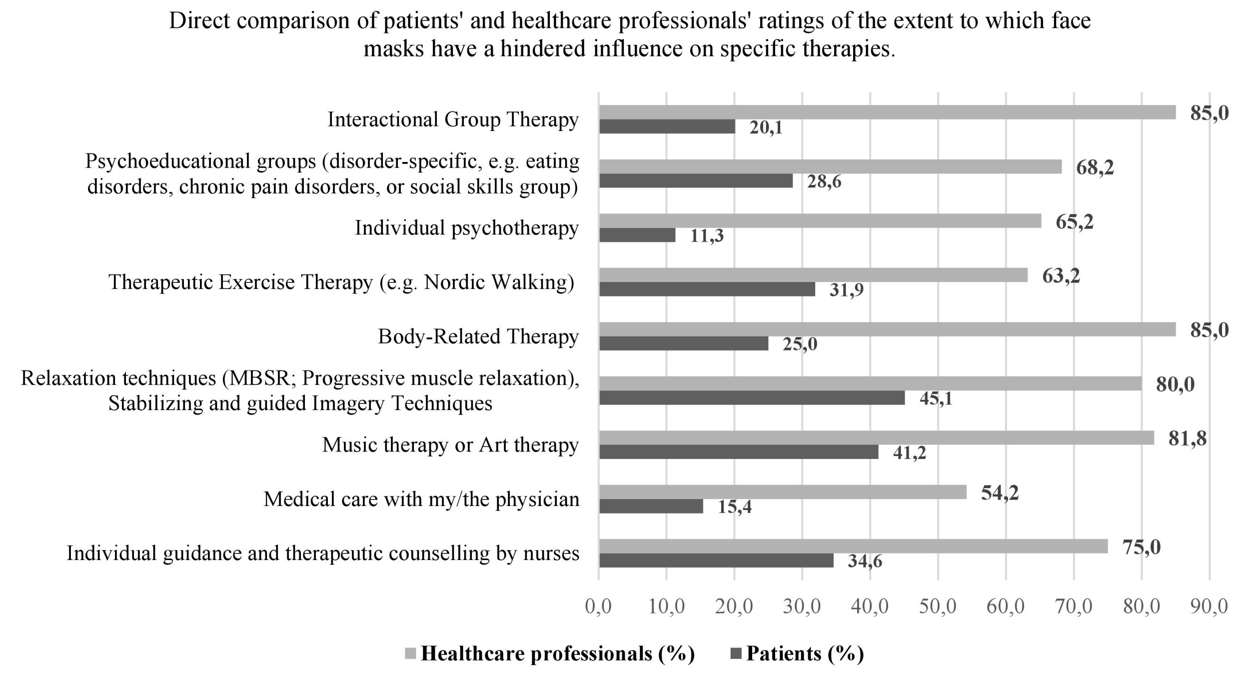

FIGURE 2
Illustration of the ratings, shown as percentages of frequency of patients (n = 55) and healthcare professionals (n = 28) interviewed regarding a disturbing effect by the face masks on various types of therapy. The percentages refer to the "applicable percentages" of the individual items.

ability) increased positive feedback, more appreciative language, more intensive validation, more unambiguous language were, however, more likely to be used with patients with complex disorders such as anxiety, post-traumatic stress disorders, major depression, and comorbid personality disorders, as well as in conflict situations.

Only 11.3% of the interviewed patients reported an interfering experience with the face mask in the individual therapy. In the further analysis (multiple answers were possible): from out of the seven of the 55 interviewed patients who stated a negative influence of the face mask, six patients stated that they felt less understood. Three patients stated that the face mask prevented them from working with the psychotherapist to achieve common goals/aims and five of the patients experienced an inhibition to address relevant topics in therapy. Furthermore, 80% of all interviewed patients stated that they felt understood by their psychotherapists despite the face mask, more than 90% of the patients perceived the psychotherapists as "honest." A total of 84% even declared that they could trust and 93% stated that they felt well supported by their psychotherapists.

In total, 85% of the healthcare professionals stated that the face masks had an interfering effect on the interactional group therapy, while only 21% of the patients generally assessed it this way. In a detailed evaluation, 29% of these patients then stated that they had difficulties in communicating with the psychotherapists and with other patients in the group. More than 38% saw a barrier in showing their true feelings to the other group members. A total of 32% said that the face masks made them less aware of their effect on the other patients in the group and 34% admitted that the face mask made it more difficult to react to challenging situations in the group. The healthcare professionals stated in the free text fields that patients with impaired hearing and patients with language barriers in particular had increased problems in group therapy due to the face mask.

Communication, emotion, and relationships

About 86% (n = 19) of the healthcare professionals stated that face masks changed the way they formed relationships with the patients. The majority of patients (84.9%), reported that the face mask did not prevent them from approaching staff (or fellow patients) and asking for help. A total of 78.8% of the patients (89% of the healthcare professionals, respectively) said that they used alternative means of communication because of the face masks. The eye area and eye movements, the tone of voice and the reaction of the forehead or eyebrows were mentioned most frequently.

Concerning the interaction and relationship formation, the patients particularly stated in the free text fields that they have difficulties understanding and expressing humorous remarks and irony and that misinterpretations and misunderstandings tend to occur between the patients rather than with the staff. However, the face mask also helps them to differentiate their own feelings and needs from other patients and healthcare professionals. Nevertheless, it is more problematic to perceive emotions and the wellbeing of other patients in order to then help other patients. The patients stated that the face masks inhibit personal (physical) contact with fellow patients and staff. Many patients criticized the lack of a "handshake" or "consolatory touch" on the shoulder by the professional team.

Several patients stated a feeling of "anonymization" and "isolation," which, however, would not be permanent. Many patients stated in the free text fields that the face masks as a "common evil" had strengthened the feeling of solidarity within the patient group. On the part of the Healthcare professionals, 85% denied a "we-feeling" created by the face masks. The healthcare professionals stated that the face masks changed the way they communicated with colleagues (n = 16; 61.6%). They were more likely to speak in a consciously friendly, clear, and direct way (42%). As a result of the face masks and distance regulations, there was less exchange about hospital structures (n = 23; 85.2%) and less interchange about patients (n = 15; 55.6%). Over 65% found themselves less attached to colleagues and 45% found themselves alienated by the face masks. Moreover, many of them stated in the free text fields that the consultation situation, the arrangement of breaks and therapy planning were also negatively changed by this feeling of alienation.

Discussion

The aim of this study was to assess the multifaceted impact of face masks during the challenging circumstances of the corona pandemic on both ends: patients and health professionals. The majority of patients and healthcare professionals somehow reported an impact of the masks on psychotherapy, however, healthcare professionals had greater concerns about masked therapy than patients. Also, perceptions strongly differed for different types of therapy: healthcare professionals saw the greatest negative influence of face masks for interactional group therapy, body therapy, music and art therapy. Patients reported an especially negative impact during relaxation and stabilization techniques, music and art therapy followed by individual guidance and therapeutic counseling by nurses. One possible explanation for the diverging results might be that patients have different expectations of non-verbal therapies such as music, art, and body-oriented therapies (Junne and Zipfel, 2016). Since communication in non-verbal therapies is of secondary importance, patients may find it more difficult to fully engage in therapy despite the mask. As wearing of masks requires the use of other communication channels, over 85% of respondents reported using alternative means of communication given the face masks which mostly included the eye area and eye movements, tone of voice, and forehead or eyebrow responses.

On health professional side, masks lead to louder, more clearly and kindly communication. In line with this, Hüfner et al. (2020) conclude that raising emotional awareness in patients with mental disorders (and perhaps in the healthcare professionals themselves) occurs by addressing the "masked emotions" directly and explicitly. Nevertheless, the majority of healthcare professionals stated that the mask did not have a great impact on the content of their sessions as that they do not consciously work in a more resource-oriented or less confrontational or exposed way, except for particularly sensitive patient groups and in conflict situations. In line with this, Barrick et al. (2021) found an increase in the usage of facial visual features with increasing mask exposure. The more people interacted with other mask wearers, the more they learned to focus on visual cues from the eye area of the face, which can also be transferred to clinical interactions in the hospital.

The greatest difference concerning the negative influence of face masks was found within individual therapy on both ends, professionals and patients especially for the aspects of "being understood by the therapist," "my therapist means it honestly," and "being able to trust the patient." Although there are mixed findings on the assessment of the trustworthiness of a counterpart wearing a face mask, an overall tendency toward a negative bias in the assessment of trustworthiness can be derived from current literature (e.g., Carbon, 2020; Gabrieli and Esposito, 2021; Marini et al., 2022).

Our results find support by Biermann et al. (2021) who found a negatively biased perception of trustworthiness in faces covered with a face mask among healthy individuals. This link was amplified by the experience of high distress which also applies for highly strained healthcare professionals during the pandemic. Gabrieli and Esposito (2021) showed that, compared to a non-mask condition, age, and gender of the counterpart had an influence on the subjective perception of trust in masked interaction partners. Adults and older individuals and individuals of different gender were perceived to be less trustworthy when wearing a mask. These findings can be used to identify factors that influence the development of trust in psychotherapy and, if possible, to take them into account in the selection of the therapist-patient dyad. Similarly, Cannito et al. (2022) found effects on decision-making patterns in interactions with masked, untrustworthy interaction partners.

Based on the evidence on the effect of covering the lower half of the face, the use of transparent face masks can be considered since they do not impair emotion recognition and trust attribution (Marini et al., 2021). Especially for structurally impaired patients and for patients suffering from disorders who are known to have a negative bias on facial recognitions such as borderline personality disorder (Domes et al., 2009) or schizophrenia (Ventura et al., 2013) transparent masks might serve as a useful tool.

Other striking differences were found concerning the social sense of belonging between and also within the groups. On the one hand, patients perceived the mask as a sign of "feeling connected," or as a "sorrow shared." Also 85% of patients said that the face mask did not discourage them from approaching staff (or fellow patients) or asking for help. On the other hand, concerning interactional group therapy, the patients stated that due to the face masks there is a barrier in "showing feelings" in the group. The patients also particularly expressed that they had difficulties in responding to ambiguous remarks or in adequately perceiving requests for help from other patients. Indeed, these observations align well with the existing literature, which shows that the reading and interpretation of emotions can be "severely" disturbed by the presence of a mask, and that confusion and misinterpretation of certain emotions can occur (Carbon, 2020; Lau, 2021; Grahlow et al., 2022). Also, these results are in line with general findings on impaired social interaction skills (for instance shaping and initiating social interactions, impairments concerning theory of mind) that can be symptom and cause of psychiatric diseases (Schilbach et al., 2013). On the positive side, this new "shared experience" of social interaction and finding alternative ways to get in touch with each other may have a positive and community-building effect. However, practitioners reported a sense of alienation and anonymization from the team. Current literature suggests that face masks not only reduce the ability to accurately categorize emotional expressions, they also make the other person seem less "close," less trustworthy, likeable, and intimate (Biermann et al., 2021; Grundmann et al., 2021). It can be assumed that the practitioner's perception was also due to an actual enforced individualization since otherwise usual group meetings and common meals were no longer possible during the pandemic.

Concerning feasibility, both sides raised concerns and complaints wearing the mask yet on the patients side, concerns were more accentuated and related to mental health problems, such as increased feeling of fear or panic. On the practitioner side, it was pointed out that climbing stairs was impaired wearing a mask. Steinhilber et al. (2022) investigated whether wearing a medical face mask (MedMask) affects the physical ability to work. Yet, they found that wearing face masks for infection prevention measures during the COVID-19 pandemic does not lead to any relevant additional physical demands, although a slightly higher breathing effort is required. It can be assumed that the findings were attributable to the time of the study and the fact that the familiarization effect of wearing a mask has not yet occurred.

During this study, the team of healthcare professionals was entrusted with daily changing regularities (testing, taking fevers, keeping distances, hygiene measures, isolation, etc.) in addition to providing medically and therapeutically care to their patients. Possibly, the assessments of the influence of the face masks in psychotherapy are also affected by these aspects above. Most patients stated in the last free text field on the questionnaire that they were very grateful that further psychotherapeutic counseling could be offered despite the current pandemic. This form of gratefulness could also influence the rather marginal-negative assessment of the patients.

To the best of our knowledge, this is the first study that examined bilateral therapeutic experiences in an in-patient setting during the early phases of the pandemic between July and October 2020. Hospitals represent highly complex workplaces characterized by high demands and low levels of control anyway. Work-related stress, reduced wellbeing, burnout and symptoms of mental illness such as depression are prevalent among healthcare professionals (e.g., Schulz et al., 2009; Klein et al., 2011; Mulfinger et al., 2020). Healthcare professionals often manifest attitudes and behaviors that are characterized by a high level of commitment and self-overload, with little ability to distance themselves from professional problems. Since the beginning of 2020, hospital employees have been additionally burdened by the acute health crisis due to the COVID-19 pandemic (Sanghera et al., 2020; Vindegaard and Benros, 2020). Direct contact with patients, quarantine experiences, and perceived health risks were identified as risk factors for increased stress (e.g., Mulfinger et al., 2020).

This report presents the subjective results of the survey of patients' and healthcare professionals' self and peer assessments, which are always susceptible to bias. We conducted the study during a period when there is little chance of habituation effects from mask wearing. Most patients had previous psychotherapy experience without a mask. Nevertheless, not conducting a randomized controlled trial, we cannot make causal statements about the quantitative and qualitative effects of face masks on the three dimensions of (i) feasibility, (ii) psychotherapeutic treatment, and (iii) communication, emotion, and relationships. The rapidly changing situational factors and the inter- and intrapsychic reactions toward those factors will possibly make the associations found here appear different when the survey is repeated at a later point in time. A direct influence of masked psychotherapy on the attainment of individual therapy objectives, conflict -and symptom management, and relationship skills cannot be assessed with this study either. The response rate for this survey was high with over 95% (for patients) and over 86% (for health professionals), but we refer to our sample size of $N = 83$ participants as a possible limitation.

The results from this study indicate that the face mask leads to more negative assessments on the part of the healthcare professionals than on the part of the patients. The majority of the patients evaluate their psychotherapy as very profitable in spite of the mask. In individual therapy, the mask seems to have a rather marginal influence on psychotherapy and the relationship with the psychotherapist as seen by the patients. Most patients stated that they used alternative cues. In interactional group therapy, the effects of the mask were interfering. Patients should be informed about the possible influences of the face mask on the recognition of emotions, possible misinterpretations and possibilities of compensation through alternative stimuli (e.g., area of the eyes) and encouraged to ask for information. Especially in group therapy, with patients from other cultural backgrounds and when assistance is needed (e.g., impaired hearing) or in cases of profound mental illness, non-verbal gestures, and body language should be matched to the intended emotional expression. Mitzkovitz et al. (2022) have compiled suggestions for conducting masked psychotherapy in their review article.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The responsible Ethics Committee of the University Hospital and Medical Faculty of the University of Tübingen was informed and reviewed the project (project number 685/2002A). For completely anonymous data, consultation and approval on the collection, analysis and publication by the ethics committee is not required. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

RE was mainly responsible for the conception and design of the study and wrote the first draft of the manuscript. KEG, AH-W, SZ, and FJ gave substantial input. CW acquired the data. RE, SHA, and CW analyzed and interpreted the data with substantial input from HW, TF-W, and NM. RE and SHA drafted the table and figures. RE, SHA, and KEG drafted the revision of the manuscript. All authors commented and revealed the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Barrick, E. M., Thornton, M. A., and Tamir, D. I. (2021). Mask exposure during COVID-19 changes emotional face processing. *PLoS One* 16:e0258470. doi: 10.1371/journal.pone.0258470

Biermann, M., Schulze, A., Unterseher, F., Atanasova, K., Watermann, P., Krause-Utz, A., et al. (2021). Trustworthiness appraisals of faces wearing a surgical mask during the Covid-19 pandemic in Germany: an experimental study. *PLoS One* 16:e0251393. doi: 10.1371/journal.pone.0251393

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Brooks, S. K., Webster, R. K., Smith, L. E., Woodland, L., Wessely, S., Greenberg, N., et al. (2020). The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *Lancet* 395, 912–920. doi: 10.1016/S0140-6736(20)30460-8

Busch, I. M., Moretti, F., Mazzi, M., Wu, A. W., and Rimondini, M. (2021). What we have learned from two decades of epidemics and pandemics: a systematic review and meta-analysis of the psychological burden of frontline healthcare workers. *Psychother. Psychos.* 90, 178–190. doi: 10.1159/000513733

Cannito, L., Anzani, S., Bortolotti, A., Di Domenico, A., and Palumbo, R. (2022). Face mask reduces the effect of proposer's (un) trustworthiness on intertemporal and risky choices. *Front. Psychol.* 13:926520. doi: 10.3389/fpsyg.2022.926520

Cannito, L., Di Crosta, A., Palumbo, R., Ceccato, I., Anzani, S., La Malva, P., et al. (2020). Health anxiety and attentional bias toward virus-related stimuli during the COVID-19 pandemic. *Sci. Rep.* 10, 1–8. doi: 10.1038/s41598-020-73599-8

Carbon, C.-C. (2020). Wearing face masks strongly confuses counterparts in reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Cataldo, F., Chang, S., Mendoza, A., and Buchanan, G. (2021). A perspective on client-psychologist relationships in videoconferencing psychotherapy: literature review. *JMIR Ment. Health* 8:e19004. doi: 10.2196/19004

Danet, A. D. (2021). Psychological impact of COVID-19 pandemic in Western frontline healthcare professionals. A systematic review. *Med. Clín.* 156, 449–458. doi: 10.1016/j.medcle.2020.11.003

Domes, G., Schulze, L., and Herpertz, S. C. (2009). Emotion recognition in borderline personality disorder-a review of the literature. *J. Pers. Disord.* 23, 6–19. doi: 10.1521/pedi.2009.23.1.6

Dragioti, E., Li, H., Tsitsas, G., Lee, K. H., Choi, J., Kim, J., et al. (2022). A large-scale meta-analytic atlas of mental health problems prevalence during the COVID-19 early pandemic. *J. Med. Virol.* 94, 1935–1949. doi: 10.1002/jmv.27549

Ekman, P., and Rosenberg, E. L. (2020). *What the Face Reveals: Basic and Applied Studies of Spontaneous Expression Using the Facial Action Coding System (FACS)*. Oxford: Oxford University Press.

Flückiger, C., Del Re, A. C., Wampold, B. E., and Horvath, A. O. (2018). The alliance in adult psychotherapy: a meta-analytic synthesis. *Psychotherapy* 55, 316–340. doi: 10.1037/pst0000172

Foley, G. N., and Gentile, J. P. (2010). Nonverbal communication in psychotherapy. *Psychiatry* 7, 38–44.

Fonagy, P., and Allison, E. (2014). The role of mentalizing and epistemic trust in the therapeutic relationship. *Psychotherapy* 51:372. doi: 10.1037/a0036505

Gabrieli, G., and Esposito, G. (2021). Reduced perceived trustworthiness during face mask wearing. *Eur. J. Investig. Health Psychol. Educ.* 11, 1474–1484. doi: 10.3390/ejihpe11040105

Grahlow, M., Rupp, C. I., and Derntl, B. (2022). The impact of face masks on emotion recognition performance and perception of threat. *PLoS One* 17:e0262840. doi: 10.1371/journal.pone.0262840

Grawe, K. (1997). Research-informed psychotherapy. *Psychother. Res.* 7, 1–19. doi: 10.1080/10503309712331331843

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hüfner, K., Hofer, A., and Sperner-Unterweger, B. (2020). On the difficulties of building therapeutic relationships when wearing face masks. *J. Psychosom. Res.* 138:110226. doi: 10.1016/j.jpsychores.2020.110226

Jones, E. A. K., Mitra, A. K., and Bhuiyan, A. R. (2021). Impact of COVID-19 on mental health in adolescents: a systematic review. *Int. J. Environ. Res. Public Health* 18:2470. doi: 10.3390/ijerph18052470

Junne, F., and Zipfel, S. (2016). The art of healing: art therapy in the mental health realm. *Lancet Psychiatry* 3, 1006–1007. doi: 10.1016/S2215-0366(16)3 0210-3

Klein, J., Frie, K. G., Blum, K., and Von Dem Knesebeck, O. (2011). Psychosocial stress at work and perceived quality of care among clinicians in surgery. *BMC Health Serv. Res.* 11:109. doi: 10.1186/1472-6963-11-109

Lau, W. K. (2021). Face masks bolsters the characteristics from looking at a face even when facial expressions are impaired. *Front. Psychol.* 12:704916. doi: 10.3389/fpsyg.2021.704916

Lin, T., Heckman, T. G., and Anderson, T. (2022). The efficacy of synchronous teletherapy versus in-person therapy: a meta-analysis of randomized clinical trials. *Clin. Psychol. Sci. Pract.* 29, 167–178. doi: 10.1037/cps0000056

Malik, S., Mihm, B., and Reichelt, M. (2021). The impact of face masks on interpersonal trust in times of COVID-19. *Sci. Rep.* 11, 1–9. doi: 10.1038/s41598-021-96500-7

Mander, J., Vogel, E., Wiesner, V., Blanck, P., and Bents, H. (2016). Yaloms wirkfaktoren in der gruppentherapie. *Psychotherapeut* 61, 384–392. doi: 10.1007/s00278-016-0119-y

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Marini, M., Paglieri, F., Ansani, A., Caruana, F., and Viola, M. (2022). Facial impression of trustworthiness biases statement credibility unless suppressed by facemask. *Curr. Psychol.* doi: 10.1007/s12144-022-03277-7 [Epub ahead of print].

Mazza, C., Ricci, E., Biondi, S., Colasanti, M., Ferracuti, S., Napoli, C., et al. (2020). A nationwide survey of psychological distress among italian people during the COVID-19 pandemic: immediate psychological responses and associated factors. *Int. J. Environ. Res. Public Health* 17:3165. doi: 10.3390/ijerph17093165

Mitzkovitz, C., Dowd, S. M., Cothran, T., and Musil, S. (2022). The eyes have it: psychotherapy in the era of masks. *J. Clin. Psychol. Med. Settings* 29, 886–897. doi: 10.1007/s10880-022-09856-x

Mulfinger, D. B. H. N., Lampl, J., Dinkel, A., Weidner, K., Beutel, M. E., Jarczok, M. N., et al. (2020). Psychische belastungen durch epidemien bei beschäftigten im gesundheitswesen und implikationen für die bewältigung der corona-krise: eine literaturübersicht. *Z. Psychosom. Med. Psychother.* 66, 220–242.

Pavlova, M. A., and Sokolov, A. A. (2021). Reading covered faces. *Cerebr. Cortex* 32, 249–265. doi: 10.1093/cercor/bhab311

Pierce, M., Hope, H., Ford, T., Hatch, S., Hotopf, M., John, A., et al. (2020). Mental health before and during the COVID-19 pandemic: a longitudinal probability sample survey of the UK population. *Lancet Psychiatry* 7, 883–892. doi: 10.1016/S2215-0366(20)30308-4

Poletti, B., Tagini, S., Brugnera, A., Parolin, L., Pievani, L., Ferrucci, R., et al. (2021). Telepsychotherapy: a leaflet for psychotherapists in the age of COVID-19. A review of the evidence. *Counsel. Psychol. Q.* 34, 352–367. doi: 10.1080/09515070.2020.1769557

Salazar de Pablo, G., Vaquerizo-Serrano, J., Catalan, A., Arango, C., Moreno, C., Ferre, F., et al. (2020). Impact of coronavirus syndromes on physical and mental health of health care workers: systematic review and meta-analysis. *J. Affect. Disord.* 275, 48–57. doi: 10.1016/j.jad.2020.06.022

Sanghera, J., Pattani, N., Hashmi, Y., Varley, K. F., Cheruvu, M. S., Bradley, A., et al. (2020). The impact of SARS-CoV-2 on the mental health of healthcare workers in a hospital setting—A systematic review. *J. Occup. Health* 62:e12175. doi: 10.1002/1348-9585.12175

Santomauro, D. F., Mantilla Herrera, A. M., Shadid, J., Zheng, P., Ashbaugh, C., Pigott, D. M., et al. (2021). Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. *Lancet* 398, 1700–1712. doi: 10.1016/S0140-6736(21)02143-7

Schilbach, L., Timmermans, B., Reddy, V., Costall, A., Bente, G., Schlicht, T., et al. (2013). Toward a second-person neuroscience. *Behav. Brain Sci.* 36, 393–414. doi: 10.1017/S0140525X12000660

Schulte, D. (1996). *Therapieplanung*. Göttingen: Hogrefe.

Schulz, M., Damkroger, A., Heins, C., Wehlitz, L., Lohr, M., Driessen, M., et al. (2009). Effort-reward imbalance and burnout among German nurses in medical compared with psychiatric hospital settings. *J. Psychiatr. Ment. Health Nurs.* 16, 225–233. doi: 10.1111/j.1365-2850.2008.01355.x

Steinhilber, B., Seibt, R., Gabriel, J., Brountsou, J., Muljono, M., Downar, T., et al. (2022). Effects of face masks on physical performance and physiological response during a submaximal bicycle ergometer test. *Int. J. Environ. Res. Public Health* 19:1063. doi: 10.3390/ijerph19031063

Ventura, J., Wood, R. C., Jimenez, A. M., and Hellemann, G. S. (2013). Neurocognition and symptoms identify links between facial recognition and emotion processing in schizophrenia: meta-analytic findings. *Schizophr. Res.* 151, 78–84. doi: 10.1016/j.schres.2013.10.015

Vindegaard, N., and Benros, M. E. (2020). COVID-19 pandemic and mental health consequences: systematic review of the current evidence. *Brain Behav. Immun.* 89, 531–542. doi: 10.1016/j.bbi.2020.05.048

Watzlawick, P. (1969). "ua: menschliche kommunikation," in *Formen, Störungen, Paradoxien*, eds P. Watzlawick, D. D. Jackson, and J. H. Beavin (Göttingen: Hogrefe).

Wieser, M., and Brosch, T. (2012). Faces in context: a review and systematization of contextual influences on affective face processing. *Front. Psychol.* 3:471. doi: 10.3389/fpsyg.2012.00471

Wong, C. K. M., Yip, B. H. K., Mercer, S., Griffiths, S., Kung, K., Wong, M. C.-S., et al. (2013). Effect of facemasks on empathy and relational continuity: a randomised controlled trial in primary care. *BMC Fam. Pract.* 14:200. doi: 10.1186/1471-2296-14-200

Xiong, J., Lipsitz, O., Nasri, F., Lui, L. M. W., Gill, H., Phan, L., et al. (2020). Impact of COVID-19 pandemic on mental health in the general population: a systematic review. *J. Affect. Disord.* 277, 55–64. doi: 10.1016/j.jad.2020.0 8.001

Zipfel, S., Stengel, A., and Junne, F. (2020). Psychotherapie in Zeiten der Covid-19-pandemie – Eine kurze reflexion. *Psychother. Psychosom. Med. Psychol.* 70, 269–271. doi: 10.1055/a-1180-0529

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The effect of masks on the recognition of facial expressions: A true-to-life study on the perception of basic emotions

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Mouth-to-nose face masks became ubiquitous due to the COVID-19 pandemic. This ignited studies on the perception of emotions in masked faces. Most of these studies presented still images of an emotional face with a face mask digitally superimposed upon the nose-mouth region. A common finding of these studies is that smiles become less perceivable. The present study investigated the recognition of basic emotions in video sequences of faces. We replicated much of the evidence gathered from presenting still images with digitally superimposed masks. We also unearthed fundamental differences in comparison to existing studies with regard to the perception of smile which is less impeded than previous studies implied.

KEYWORDS

emotion perception, face masks, social interaction, interpersonal communication, video stimulus, basic emotions, COVID-19

1. Introduction

In the light of the COVID-19 pandemic, face masks are used in everyday life to reduce the transmission of the SARS-CoV-2 virus. However, face masks do not only play a central role in infection control, but they also have an impact on social interaction. For the first time in (western) history, the faces of communication partners have been systematically obscured in public for months and years. According to Carbon (2020), about 60–70% of facial areas relevant for the expression of emotions are thus hidden. Since the end of the pandemic cannot yet be foreseen, one must assume that face masks will accompany us for some time to come. From a psychological perspective the question arises to what extent these masks influence the recognition of facial emotion for interlocutors. The present study is the first of its kind to use naturally moving faces to investigate experimentally how face masks affect emotion recognition.

The most popular methodology for categorizing facial emotions is the so-called *Facial Action Coding System* (FACS) by Ekman et al. (2002). FACS is a categorical system for determining facial expressions based on the smallest visually perceptible facial movements, called *Action Units* (AUs). Psychometric evaluations of the FACS show good to excellent interrater reliability in coding the occurrence, intensity, and timing of specific AUs (Sayette et al., 2001). Likewise, several studies demonstrated high validity when comparing the FACS manual with computer-based methods for analyzing facial expressions and thus various automated detection systems are continuously developed and further improved (e.g., Bartlett et al., 1999; Cohn et al., 1999; Pantic and Patras, 2006; Baltrusaitis et al., 2018; Yudiarso et al., 2020). Most of these computers assisted and automated systems are based on the so-called "Basic emotions" paradigm - that is; Sadness, Anger, Surprise, Fear, Disgust, Contempt and Happiness - also formulated by Ekman (1999) and widely accepted in the scientific community as valid constructs of interculturally observable human behavior.

Since the start of the pandemic, several studies have investigated the effects of facial masks on emotion recognition and interpretation. However, so far only static pictures of displayed emotions (obtained from, e.g., MPI Facial Expression Database (Kaulard et al., 2012), Matsumoto and Ekman database (1988) or DANVA2-AF Diagnostic Analysis of nonverbal Accuracy) have been widely used in the respective study designs. As these databases offer only maskless faces, masks have been simply added digitally and compared to the original faces in these experimental designs (e.g., Carbon, 2020; Ruba and Pollak, 2020; Bani et al., 2021; Calbi et al., 2021; Gori et al., 2021; Grundmann et al., 2021; Marini et al., 2021; Pazhoohi et al., 2021; Sheldon et al., 2021; Grahlow et al., 2022; Kim et al., 2022). Hofmann et al., 2021 used - additionally to their also experimentally used and digitally altered still photographs of displayed emotions - a multimethod setting that provides a more holistic insight into human perception and experience with masked and unmasked frontline employees from a customer viewpoint. Kastendieck et al. (2022) digitally placed surgical masks on existing video footage. However, the predominant use of "static-image-methodology" is not surprising as even before the pandemic, empirical questions on the perception and interpretation of nonverbal facial behavior were predominantly evaluated with still images (Paiva-Silva et al., 2016).

Only the minority of studies conducted so far report no general strong influence of masks on emotion recognition (Ruba and Pollak, 2020; Calbi et al., 2021; Kastendieck et al., 2022). In contrast, most studies conclude an overall significant influence on the perception and interpretation of facial emotions when a mask is worn:

- Most studies find that recognition of *anger* is impaired when the corresponding faces were presented with a mask (Carbon, 2020; Bani et al., 2021; Grahlow et al., 2022; Pazhoohi et al., 2021; Kim et al., 2022).
- The detection of *disgust* also consistently showed significant limitations due to wearing a mask (Carbon, 2020; Grahlow et al., 2022; Pazhoohi et al., 2021; Kim et al., 2022). Additionally, the recognition of disgust was the most impaired of all emotions in two studies (Carbon, 2020; Grahlow et al., 2022).
- *Sadness* was also significantly less detectable with mask in Bani et al. (2021), Carbon (2020), Grahlow et al., (2022), Kim et al. (2022), Marini et al. (2021), and Pazhoohi et al. (2021). In contrast, Kastendieck et al. (2022) - conducting a video-based study design, but with only digitally added masks - found no difference in the expression of sadness between masked and unmasked trials.
- Except for studies from Marini et al. (2021) and Pazhoohi et al. (2021), masks did not show any limitations in detecting *fear* (Carbon, 2020; Bani et al., 2021; Grahlow et al., 2022). Kim et al. (2022) additionally showed that covering the eye region by wearing sunglasses leads to significant limitations in emotion recognition of fear - while there were no significant differences between stimuli with and without mouth-nose protection.
- Regarding *happiness*, previous studies provide the most inconsistent results: Bani et al. (2021), Carbon (2020), Kim et al. (2022), Marini et al. (2021), and Pazhoohi et al. (2021) found that joyful faces were significantly worse to identify while wearing a mask. In contrast, in the studies by Grahlow et al., (2022), Hofmann et al. (2021) and Kastendieck et al. (2022) emotion recognition with a mask was not impaired for happiness. Furthermore, Sheldon et al. (2021) were the first and so far only study to investigate the effect of mouth-nose protection on Duchenne (sincere) vs. social (insincere) smiles. Study participants were presented with photos of faces showing either a Duchenne smile, a social smile, disgust, or a neutral expression with and without a mask. Afterwards, the subjects were asked to rate to what extent the individual photos depicted the four emotions. Results showed that a masked social smile was perceived as significantly more neutral and less friendly than an unmasked social smile. In case of the Duchenne smile, in contrast, the mask affected the perception of friendliness significantly less.
- In most studies, a masked *neutral* expression could still be identified as such (Carbon, 2020; Grahlow et al., 2022; Marini et al., 2021; Kim et al., 2022); only in the study by Pazhoohi et al. (2021) participants had more difficulty to identify neutral faces when they were masked.

In brief, the key findings of the conducted studies to date can be summed up as follows.

- Anger, disgust, sadness, happiness (social as well as Duchenne) are significantly harder to identify when masked
- The identification of fear and neutral expressions is not affected by masks

As outlined above, most studies that found a significant influence of masks on the ability to perceive emotions have been conducted with photos - with masks digitally superimposed. These depictions are static, mostly showing the emotional expression at its "peak" without the variations an emotional expression encompasses in its due course. For a more true-to-life evaluation of the perception of emotion in masked faces, video material is - most probably - more suitable. Facial emotions are composed of a multitude of simultaneously (more or less intensively) activated muscle groups.

Moreover, these signals are transient - affecting the communication partner over a period of time in different degrees. A static image cannot adequately reflect this complexity. In addition, a massively limiting factor in the perception of emotions in static pictures may be that the mask does not move, nor slip or wrinkle in accordance with the facial movements of expressing the emotion.

The objective of the present study was to re-investigate the perception of emotions in masked faces with an ecologically valid procedure, that is, with video sequences of facial expressions of emotions. We expect little differences to previous studies for rather "static" emotional expressions such as sadness which only involves subtle movements of facial muscles. With regard to the expression of happiness - particularly a "dishonest" (i.e., social) smile - participants may detect this expression due to the movement (i.e., elevation) of the face mask. This finding would be discrepant to existing studies with still images which reported that masked smiles were perceived as a neutral expression. An honest smile might be the easiest emotion to perceive because of the elevation of the mask and the presence of the Duchenne marker.

2. Materials and methods

2.1. Participants

A total of 267 participants (188 female, 78 male and 1 divers) with a mean age of 31 years (SD = 15) participated in the online survey. About half (57%) of the sample were students, the other participants had various professions. The students were reimbursed for their efforts with course credits. Every participant additionally had the chance to win vouchers from an online marketplace. Mean completion time for the whole experiment was 32 min (SD = 14).

2.2. Material

The video clips depicted a caucasian actor and an actress performing the action units (AUs), that is, happiness (social vs. Duchenne smile), anger, disgust, sadness, fear and neutral. Written informed consent was obtained from the actors for publication of images and video material. The actors - with years of professional experience - were thoroughly instructed on the relevant features in facial expression that defined the respective AUs. If necessary, the actors were re-instructed and given feedback during the preparation and recording of the video clips based on the FACS manual (Ekman et al., 2002). The AUs were repeated with the face mask (conventional surgical mask; see Figure 1). We paid attention that the (observable) facial expressions with and without the face masks were as similar as possible both during preparation, as well as during the video post-production and selections of the numerous final video clips. A pre-test assured that the depicted emotions were correctly identified when no mask was worn. Furthermore, we validated our material with the OpenFace toolkit (Baltrusaitis et al., 2018) on facial action recognition *via* several parameters such as facial landmark detection. The results of this analysis are presented in the Supplementary Material and coincide largely with AU definitions based on the FACS manual.

2.3. Procedure

The experiment was conducted online *via* the LimeSurvey plattform (Limesurvey GmbH, 2012). Access was granted between January 15 and March 29, 2022 - a period of time in which mask wearing was mandatory in all publicly accessible places across central Europe, such as supermarkets, public transport, educational institutions, asf.

The procedure of the present experiment is illustrated in Figure 1. A fixation cross on black background preceded each trial (2 s). Thereafter, a video clip presenting a basic emotion, that is, happiness (social vs. Duchenne smile), anger, disgust, sadness, fear, or a neutral expression - either masked or unmasked - was presented in such a way that the tip of the nose of the respective actor/actress aligned to the center of the screen. After a brief still image of 1 s (25 frames), the respective emotion was performed between 34 and 45 frames (about 2 s). Trial presentation was randomized for every participant. Each portrayed emotion was presented once to participants in four different versions; that is: male masked, male unmasked, female masked, female unmasked. Two familiarization trials (neutral expression) preceded the experimental run. After each video clip, the participants were asked to identify the displayed emotion, rate its intensity and rate their confidence in emotion identification on a 7-point likert scale. For the emotion happiness (i.e., social smile and Duchenne smile), the participant was further asked to rate how honest they felt the portrayed emotion.

2.4. Statistical analysis

Chi-Square tests were performed for the investigation of rating regarding participants' perception of displayed facial emotion and Wilcoxon signed-rank test was used for the investigation of participants' certainty, and in case of the happiness condition also the honesty of the displayed, masked, and unmasked facial emotion. We corrected (Bonferroni) the resulting *p*-values for the multiple comparisons. Furthermore, we report effect sizes, that is, Cramer's V for the perception of the emotions and Cohen's d for the (Likert-scaled) measures of certainty, intensity honesty.

3. Results

3.1. Perception

Table 1 presents the mean percentage of recognizing the displayed emotion without and with facial mask and the corresponding results from the Chi-square comparison. In general, the recognition of smiles (both Duchenne and social

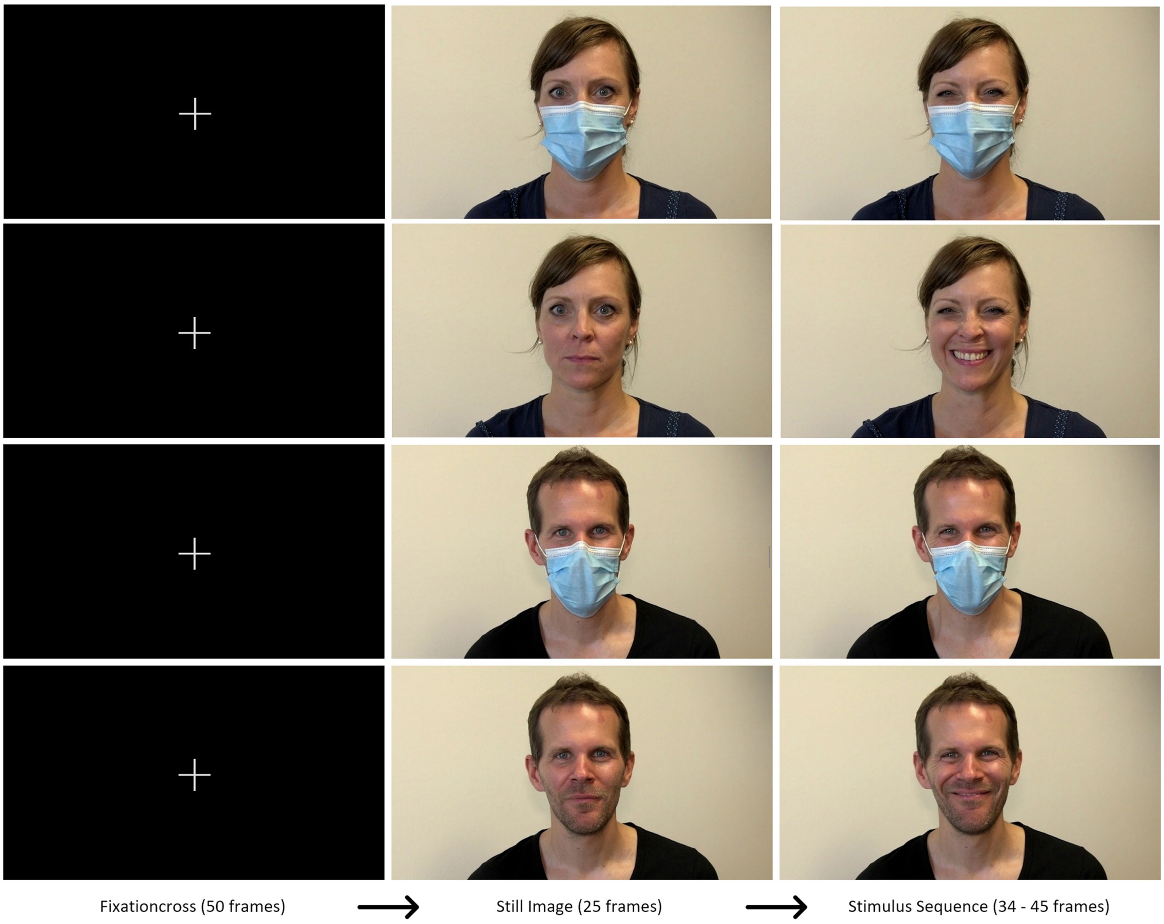

FIGURE 1
Schematic illustration of experimental trials displaying the Duchenne condition from both actors with and without mask.

TABLE 1 Mean percentage of recognizing the displayed emotion without and with a facial mask, the result from the Chi-square comparison and effect sizes (Cohen's d).

Emotion	No mask	Mask	X^2	*p*-corr	Cramer's V
Duchenne	96	88	11.15	<0.01	0.20
Social smile	93	91	0.40	1.00	0.04
Anger	73	42	51.52	<0.001	0.44
Fear	86	85	0.14	1.00	0.02
Sadness	60	27	56.36	<0.001	0.46
Disgust	80	48	57.38	<0.001	0.46
Neutral	94	95	0.31	1.00	0.03

smiles) and neutral faces were high with means of above 90%. Anger and sadness were the least often correctly identified emotions. The Chi-square tests revealed that Duchenne smiles, anger, disgust, and sadness were statistically significantly harder to recognize in masked than in unmasked faces. In contrast, social smiles, fear, and neutral expressions show no statistically significant difference in recognition with and without mask.

Sadness was more often misperceived as fear (35%) than correctly perceived as sadness. It was also often misperceived as disgust (26%). Disgust was often erroneously perceived as anger (24%) and fear (21%). Anger was often misperceived as disgust (29%) and less often as fear (17%). A complete confusion matrix is provided in the Supplementary material. We also provide the percentage of emotion recognition separately for the actress and the actor in the Supplement. Importantly, this separate analysis revealed the same pattern of results as the analysis of the male–female average. However, the actress elicited higher recognition rates of anger and sadness than for the male actor (whose masked sadness was utterly imperceivable with a recognition rate of only 4%). The actor, to the contrary, elicited a slightly higher recognition rate for the Duchenne smile than the actress.

3.2. Certainty

Table 2 presents the mean subjective certainty with which the participants recognized the displayed emotion. In general, the certainty was high for both smiles (Duchenne and social)

TABLE 2 Mean scores of the ratings how certain the participants were in recognizing the displayed emotion without and with facial mask, the result from the Wilcoxon test and effect sizes (Cohen's d).

Emotion	No mask	Mask	*Z*	*p*-corr	d
Duchenne	6.20	5.26	8.93	<0.001	0.76
Social smile	6.03	5.31	7.97	<0.001	0.56
Anger	5.31	3.99	11.21	<0.001	1.08
Fear	5.54	5.07	5.60	<0.001	0.38
Sadness	5.14	3.85	11.13	<0.001	1.08
Disgust	5.21	3.84	11.50	<0.001	1.10
Neutral	6.08	5.44	6.66	<0.001	0.50

and for neutral expressions. The participants felt less certain in response to sad, disgusted, and fearful faces. Statistically, the difference between the unmasked and the masked faces was significant for each of the emotions. Expectedly, the certainty of recognizing the emotion was higher for the unmasked faces. Numerically, the differences in certainty were highest for disgust and sadness followed by the Duchenne smile. The separate analyses for the female and the male actor revealed a similar pattern. A noteworthy difference, however, was that the certainty of perceiving anger was higher for the unmasked actress than for the unmasked actor ($Z = 11.23$, $p < 0.001$).

3.3. Intensity

Table 3 shows the mean score of how intense the participants perceived the displayed emotion without and with a facial mask. Expectedly, the neutral expression elicited the lowest intensity rating with little difference whether or not the face wore a mask (although the difference is statistically significant). Fear, disgust, sadness, and the Duchenne smile scored highest in the intensity ratings. For fear and the Duchenne smile it made little difference whether or not the faces were masked. Sadness, disgust and - on a lower level - social smile were perceived as more intense without a mask than with a mask. Separate analyses for the actress and the actor revealed the same pattern of results.

3.4. Honesty

We let the participants rate the honesty of the Duchenne and the social smile. The result is depicted in Figure 2. Expectedly, participants rated the Duchenne smile in both conditions (unmasked and masked; $M = 3.77$ and 3.90, respectively) significantly more honest than the social smile ($M = 2.37$ and 2.83; $Z = 10.22$ and $Z = 11.58$, $ps < 0.001$, $ds > 1.0$). Less expected, the participants perceived the social smile on average more honest in masked faces than in unmasked faces ($Z = 5.57$, $p < 0.001$, $d = 0.37$). The separate analysis revealed that this effect was present for both the actress and the actor ($Zs > 2.30$, $ps < 0.05$).

4. Discussion

The study set out to investigate the effect of wearing a facial mask on the perception of emotion in video sequences of faces. Considering the ubiquity of face masks due to the COVID-19 pandemic, numerous studies investigated this issue. However, these studies used portraits of faces (often from repositories) and the masks had been superimposed on the still images. We argued that the recognition of emotion in masked, but animated faces may differ from recognizing the same emotion in still images. One reason is that the expression of an emotion is a transient process and perceiving it evolving may contribute to recognition. Another and possibly an even higher weighting factor is that one can perceive the movement of the mask when the emotion unfolds as, for example, an elevation of the mask in case of a smile. Our findings are, in many aspects, similar to the findings of previous studies. There are, however, also notable differences. The results on Duchenne and social happiness seem particularly interesting. As described above, this is also where one finds the greatest differences in existing studies.

An honest smile, that is the Duchenne smile, is exceptionally easy to recognize in a fully visible face as evinced by the highest (cloze-to-ceiling) recognition rate of all the emotions of the present study. Besides the raising of the corners of the lips, this sort of smile is further characterized by the activation of the orbicularis oculi muscle and pars orbitalis muscle. Thus, the smile still has a high recognition rate even when the lower part of the face is masked (still close to 90%). However, the difference in recognition rate in the unmasked and the masked condition was statistically significant. Thus, a facial mask does impede the perception of an honest smile, albeit at a very high level of successful recognition (see also Sheldon et al., 2021).

Social ("dishonest") smiles also had a high recognition rate and - in contrast to the Duchenne smile - the mask had no (significant) effect on recognition. This finding is interesting as social smiles are primarily communicated through facial regions located under the mask. Possibly, the elevation and wrinkling of the mask plays a role in recognizing this kind of smile. Studies with still images reported that smiles are more difficult to perceive when masked (e.g., Carbon, 2020; Bani et al., 2021; Marini et al., 2021; Pazhoohi et al., 2021; Kim et al., 2022). To illustrate, Sheldon et al. (2021) conducted a study with still images of masked faces showing Duchenne smiles and social smiles. They reported that masked social smiles became non-smiles. The discrepancy of their findings and ours emphasizes the value of studying emotion perception with videos of facial expressions.

With regard to the perceived certainty of participants' interpretation of displayed emotions, the consistent difference between masked and unmasked conditions for all emotions (including neutral expressions) is noteworthy. The differences in the rating on the 7-point Likert scale amount to an average reduction of about one scale value (−0.96). The largest reduction we found was for disgust (−1.37), the smallest for anger (−0.47). However, the latter finding has to be put into perspective, because for anger we found a substantial difference in the certainty ratings for the female and the male actress. The participants were much more certain about perceiving anger in the face of the actress. In sum, the mask exerts an influence on the certainty of perceiving emotions. Likewise, masks also play a role - albeit smaller than for the rating of certainty - in the perceived intensity of the displayed emotions. All but one emotional expression was perceived less intensive in the masked faces. Perceiving the intensity of fear was not (significantly) affected by the mask. This finding together with similar recognition rates in unmasked and masked faces (consistent with Carbon, 2020; Bani et al., 2021; Grahlow et al., 2022) conforms to the evidence that the most influential feature for recognizing fear are widened eyes (e.g., Yarbus, 1967; Kim et al., 2022).

TABLE 3 Mean scores of the ratings how intense the participants perceived the displayed emotion without and with facial mask, the result from the Wilcoxon test and effect sizes (Cohen's d).

Emotion	No mask	Mask	*Z*	*p*-corr	d
Duchenne	4.45	4.22	2.57	0.07	0.18
Social smile	3.55	3.06	6.27	<0.001	0.39
Anger	4.22	3.81	5.44	<0.001	0.37
Fear	4.87	4.84	0.43	1.00	0.03
Sadness	4.62	4.05	7.31	<0.001	0.56
Disgust	4.63	4.10	6.74	<0.001	0.48
Neutral	2.97	2.73	2.99	0.02	0.12

Moreover, our results are particularly interesting with respect to the perceived honesty of the two displayed happiness conditions, that is, the Duchenne and the social smile. We found that the perceived honesty of social smiles with a mask is different from social smiles without a mask in the unexpected direction: The participants tended to rate a "fake" smile with a mask more "genuine" than without a mask. This was the case in the averaged data and for both the actress and the actor in the separate analyses (so the next time you are selling a broken car, put on a mask). Since in the upper, freely visible areas of the face muscle groups are less activated than in an "honest" Duchenne smile - little information about the displayed emotion of a social smile is available there. Thus, our finding could represent an expectancy effect that results from the movement of the mask due to the smile underneath. Since the smile cannot be processed in its entirety due to the mask, interlocutors may tend to automatically evaluate more in the direction of honesty. This is, of course, a mere speculation, but may ignite further research into the possible source of this unexpected effect.

It may be a little excursion but comparing pre-pandemic studies with the findings and implications of the studies on the

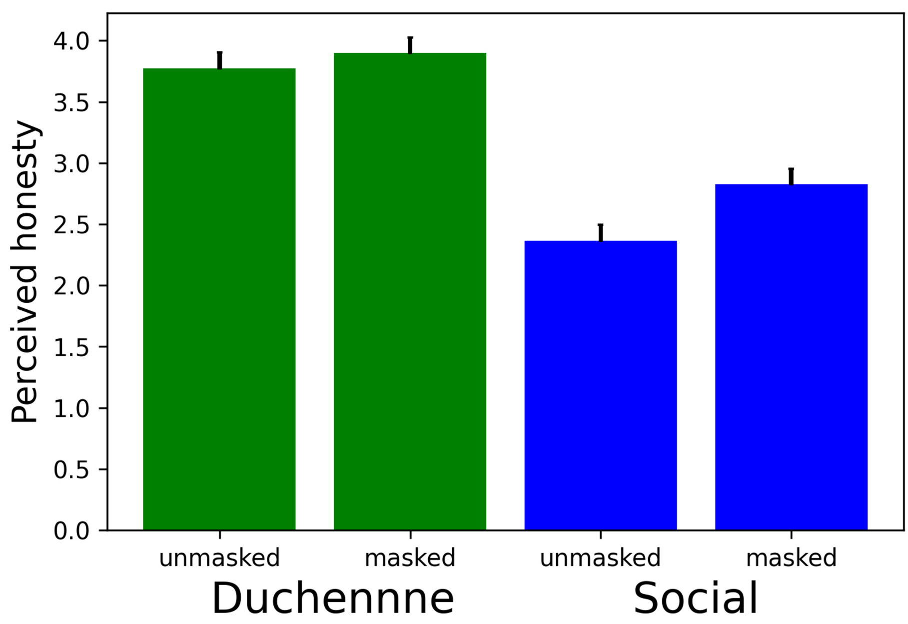

FIGURE 2
Mean honesty ratings for unmasked and masked smiles separately for an honest (Duchenne) and a dishonest (social) smile. Error bars indicate the 95% confidence interval.

effect of wearing masks on emotion recognition may be worthwhile. To illustrate, Boucher and Ekman (1975) and Wegrzyn et al. (2017) found that the most important diagnostic information for the identification of fear is in the eye area. Thus, it makes perfect sense that subjects in the mask studies were, for the most part, able to identify anxiety (e.g., Carbon, 2020; Bani et al., 2021; Grahlow et al., 2022; Kim et al., 2022). For the identification of disgust, in contrast, pre-pandemic studies (Boucher and Ekman, 1975; Wegrzyn et al., 2017) showed a clear focus on AUs in the mouth and cheek area. Accordingly, it is interesting to observe that the mask studies also showed strong limitations in emotion recognition specifically for disgust (Carbon, 2020; Grahlow et al., 2022; Pazhoohi et al., 2021; Kim et al., 2022). This is also true for happiness, the slightly inconsistent results of the mask studies (Carbon, 2020; Bani et al., 2021; Grahlow et al., 2022; Hofmann et al., 2021; Marini et al., 2021; Pazhoohi et al., 2021; Kim et al., 2022) can possibly be explained by the fact that Boucher and Ekman (1975) observed a focus on both mouth and eye region when viewing happy faces, whereas Wegrzyn et al. (2017) observed a focus on the mouth. Barrick et al. (2021) reported that there are some indications that eye cues could become more important in the reading of emotions the longer masks are worn by the general public. Consequently, research on the perception of emotional facial expressions before the introduction of masks in the course of the COVID-19 pandemic may become less representative.

The particular challenge of the present study was the creation of the video stimulus material. We had to be meticulous that in both conditions (mask / no mask) the visible (and hidden) AUs were activated as identically as possible. For this reason, we opted for a multi-stage validation process, starting with an particularly explicit instruction of the actors, through feedback and corrections during filming and the selection of the best matches in the course of post-production, to evaluation with OpenFace (see Supplementary material). The OpenFace analysis revealed that the actress and the actor expressed the smiles - both Duchenne and social - very similar, that is, by activation of the same action units (AU). The only noteworthy difference was that the actress in the Duchenne condition smiled with parted lips (i.e., open-mouthed; AU25), whereas the actor did not. Sadness and disgust were also expressed similarly by both actors, but there were quantitative differences in the activation strength of the action units. The actors did differ in expressing anger which probably contributed to the different recognition rates in this condition and leads us directly to discussing the study's limitations.

5. Limitations

It is clearly a limitation that we used stimuli from only two actors. The creation of such stimuli is costly with respect to time (see above) and human resources (if one opts, as we did, for professional actors). A replication with emotional expressions of more different faces would be time consuming, but expedient. In a similar vein, we also did not study the whole spectrum of basic emotions. Future studies may include surprise and contempt. With hindsight, another critical aspect is that we used surgical masks which - at that time - were omnipresent. In the meantime, the wearing of surgical masks waned and FFP2 masks became much more common. Had we used FFP2 masks, the findings might differ. FFP2 masks are more rigid and sit tighter on the face. Thus, one may reason that this sort of mask may affect the perception of emotional facial expressions to a greater extent and this may be particularly so for the social smile. A follow-up study with FFP2 masks would clarify this issue.

6. Conclusion

Video footage of facial emotions creates more informative context than still images. Especially against the background of topical questions regarding the effects of masks on interpersonal communication, digitally superimposed masks on photographs are artificial compared to actually worn masks in video material. Especially for more complex research questions - that go beyond answering the principal perception of basic emotions (such as, e.g., the distinction between honest and dishonest smiles) specially created stimulus material should play a more prominent role in future investigations.

Although some differences in emotion recognition, perceived certainty and intensity between masked and unmasked faces seem rather small in absolute terms, we can conclude that masks impede the interpretation of facial emotions and reduce perceived certainty and intensity. We also found, surprisingly, that masked social smiles were perceived as more honest than social smiles which were fully perceivable. Still, one perceives a Duchenne smile as more honest than a social smile regardless of whether the opponent's face is fully visible or only half visible due to a mouth-nose mask. Thus, smile and mean it - during the pandemic and afterwards - it will be appreciated!

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

FH, ML, VM, and SH: conception and design. ML and VM: data acquisition. SH, ML, and VM: analysis and interpretation of data. ML, SH, VM, and SS: writing publication. ML, FH, SS, and SH: critical revision of publication. ML and SH: supervision. ML and FH: resources. VM and SS: technical administrative and support. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.933438/full#supplementary-material

References

Baltrusaitis, T., Zadeh, A., Lim, Y.C., and Morency, L.P. (2018). "Open Face 2.0: Facial Behavior Analysis Toolkit." in *IEEE International Conference on Automatic Face & Gesture Recognition*.

Bani, M., Russo, S., Ardenghi, S., Rampoldi, G., Wickline, V., Nowicki, S. Jr., et al. (2021). Behind the mask: emotion recognition in healthcare students. *Medical Science Educator* 31, 1273–1277. doi: 10.1007/s40670-021-01317-8

Barrick, E. M., Thornton, M. A., and Tamir, D. I. (2021). Mask exposure during COVID-19 changes emotional face processing. *PLoS One* 16:e0258470. doi: 10.1371/journal.pone.0258470

Bartlett, M. S., Hager, J. C., Ekman, P., and Sejnowski, T. J. (1999). Measuring facial expressions by computer image analysis. *Psychophysiology* 36, 253–263. doi: 10.1017/S0048577299971664

Boucher, J. D., and Ekman, P. (1975). Facial areas and emotional information. *J. Commun.* 25, 21–29. doi: 10.1111/j.1460-2466.1975.tb00577.x

Calbi, M., Langiulli, N., Ferroni, F., Montalti, M., Kolesnikov, A., Gallese, V., et al. (2021). The consequences of COVID-19 on social interactions: an online study on face covering. *Sci. Rep.* 11:2601. doi: 10.1038/s41598-021-81780-w

Carbon, C. (2020). Wearing face masks strongly confuses counterparts in Reading emotions. *Front. Psychol.* 11:566886. doi: 10.3389/fpsyg.2020.566886

Cohn, J. F., Zlochower, A. J., Lien, J., and Kanade, T. (1999). Automated face analysis by feature point tracking has high concurrent validity with manual FACS coding. *Psychophysiology* 36, 35–43. doi: 10.1017/S0048577299971184

Ekman, P. (1999). "Basic emotion," in *Handbook of cognition and emotion*. eds. T. Dalgleish and M. Power (Hoboken: New Jersey), (John Wiley & Sons), 45–60.

Ekman, P., Friesen, W.V., and Hager, J.C. (2002). *The facial action coding system: A technique for the measurement of facial movement*. San Francisco, CA: Consulting Psychologists Press.

Gori, M., Schiatti, L., and Amadeo, M. B. (2021). Masking emotions: face masks impair how we read emotions. *Front. Psychol.* 12:669432. doi: 10.3389/fpsyg.2021.669432

Grahlow, M., Rupp, C. I., and Derntl, B. (2022). The impact of face masks on emotion recognition performance and perception of threat. *PLoS One* 17:e0262840. doi: 10.1371/journal.pone.0262840

Grundmann, F., Epstude, K., and Scheibe, S. (2021). Face masks reduce emotion-recognition accuracy and perceived closeness. *PLoS One* 16:e0249792. doi: 10.1371/journal.pone.0249792

Hofmann, V., Stokburger-Sauer, N. E., Wanisch, A., and Hebborn, H. (2021). Masked smiles matter - employee verbal expertise and emotion display during COVID-19. *Serv. Ind. J.* 41, 107–137. doi: 10.1080/02642069.2021.1873296

Kastendieck, T., Zillmer, S., and Hess, U. (2022). (un) mask yourself! Effects of face masks on facial mimicry and emotion perception during the COVID-19 pandemic. *Cognition Emotion* 36, 59–69. doi: 10.1080/02699931.2021.1950639

Kaulard, K., Cunningham, D. W., Bülthoff, H. H., and Wallraven, C. (2012). The MPI facial expression database - a validated database of emotional and conversational facial expressions. *PLoS One* 7:e32321. doi: 10.1371/journal.pone.0032321

Kim, G., Seong, S. H., Hong, S. S., and Choi, E. (2022). Impact of face masks and sunglasses on emotion recognition in south Koreans. *PLoS One* 17:e0263466. doi: 10.1371/journal.pone.0263466

LimeSurvey Project Team, Schmitz, C. (2012). LimeSurvey: An Open Source survey tool. LimeSurvey Project, Hamburg, Germany. Available at: http://limesurvey.org (Accessed December 11, 2022)

Marini, M., Ansani, A., Paglieri, F., Caruana, F., and Viola, M. (2021). The impact of facemasks on emotion recognition, trust attribution and re-identification. *Sci. Rep.* 11:5577. doi: 10.1038/s41598-021-84806-5

Paiva-Silva, A., Pontes, M., Aguiar, J., and de Souza, W. (2016). How do we evaluate facial emotion recognition? *Psychol. Neurosci.* 9, 153–175. doi: 10.1037/pne0000047

Pantic, M., and Patras, I. (2006). Dynamics of facial expression: recognition of facial actions and their temporal segments from face profile image sequences. *IEEE Trans. Syst. Man Cybern.* 36, 433–449. doi: 10.1109/TSMCB.2005.859075

Pazhoohi, F., Forby, L., and Kingstone, A. (2021). Facial masks affect emotion recognition in the general population and individuals with autistic traits. *PLoS One* 16:e0257740. doi: 10.1371/journal.pone.0257740

Ruba, A. L., and Pollak, S. D. (2020). Children's emotion inferences from masked faces: implications for social interactions during COVID-19. *PLoS One* 15:e0243708. doi: 10.1371/journal.pone.0243708

Sayette, M. A., Cohn, J. F., Wertz, J. M., Perrott, M. A., and Parrott, D. J. (2001). A psychometric evaluation of the facial action coding system for assessing spontaneous expression. *J. Nonverbal Behav.* 25, 167–185. doi: 10.1023/A:1010671109788

Sheldon, K. M., Goffredi, R., and Corcoran, M. (2021). The glow still shows: effects of facial masking on perceptions of Duchenne versus social smiles. *Perception* 50, 720–727. doi: 10.1177/03010066211027052

Wegrzyn, M., Vogt, M., Kireclioglu, B., Schneider, J., and Kissler, J. (2017). Mapping the emotional face. How individual face parts contribute to successful emotion recognition. *PLoS One* 12:e0177239 .0177239. doi: 10.1371/journal.pone

Yarbus, A.L. (1967). *Eye movement and vision*. Plenum: New York.

Yudiarso, A., Liando, W., Zhao, J., Ni, R., and Zhao, Z. (2020). "Validation of Facial Action Unit for Happy Emotion Detection." in *Proceedings of the 3rd International Conference on Psychology in Health, Educational, Social, and Organizational Settings*. pp. 360–363.

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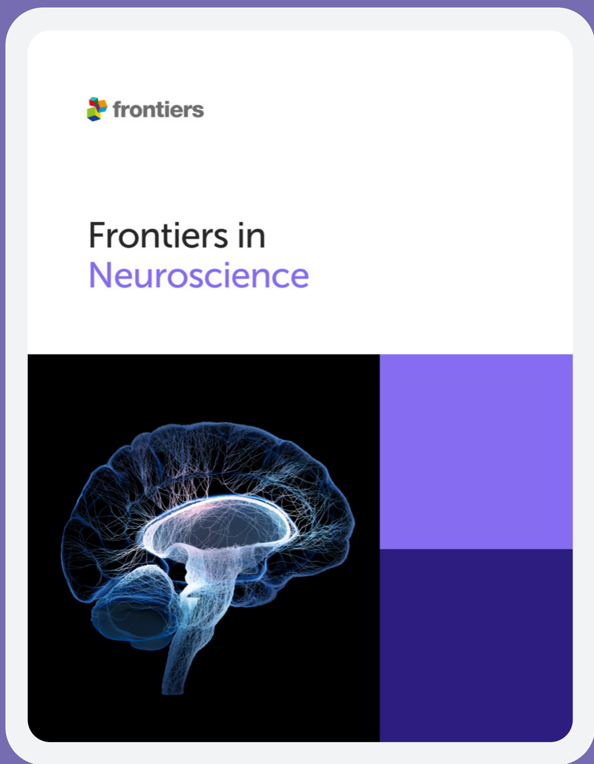

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