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Methodological issues in consciousness research

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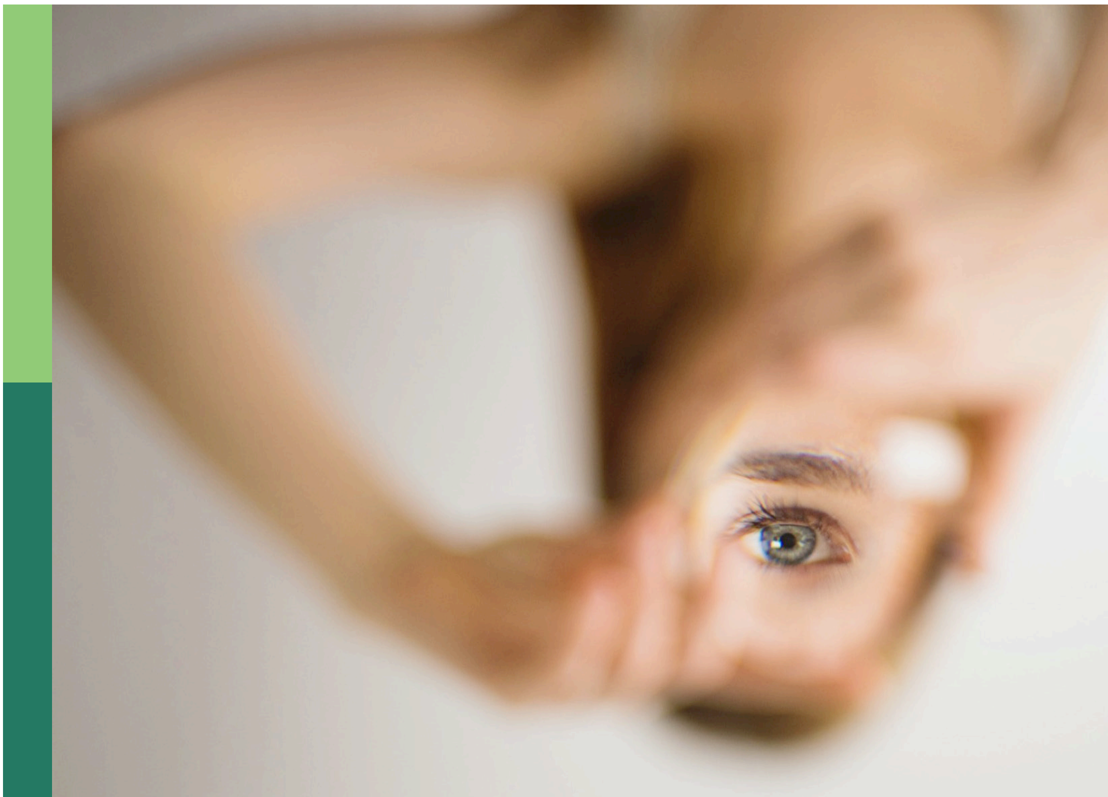

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Methodological issues in consciousness research

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Editorial: Methodological issues in consciousness research

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Editorial on the Research Topic
Methodological issues in consciousness research

The study of consciousness has been greatly shaped by the development of increasingly compelling methods to measure it, from Wundt (1897) introspection at Lipsia (Wundt, 1897), to the studies of brain lesions of the middle of the past century (see LeDoux et al., 2020) and, finally, to the search for the neural correlates of consciousness through EEG and fMRI studies (Koch et al., 2016). As methods have had such a prominent role in guiding and orienting the research on consciousness, we felt a Research Topic on Methodological Issues in Consciousness Research was timely and relevant. We aimed to assemble different contributions to the field, spanning different experimental methods, from the well-established EEG paradigm to the new zest for online behavioral studies. In the following, we offer a brief overview of the contents of each contribution.

The commentary by Moayery points out three critical issues with the model of self-control in consumer behavior as proposed by Vosgerau et al. (2020), in which self-control failures derive from the choice of violating superordinate long-term goals, putting a great emphasis on overt or conscious processes. While recognizing the value of this position, Moayery's article originally underlines the following three critical points in the formulation of Vosgerau et al. (2020), emphasizing the role of unconscious processes in determining consumer behaviors. First, the lack of self-control does not always derive from a deliberate choice between alternative goals, as people often fail to self-monitor their actions or intentions. Second, while ego-depletion theory suffers from several shortcomings, it addresses a number of real-life phenomena that should be taken into account and not rejected. Third, Vosgerau et al. (2020) model ignores the contribution of impulsive mechanisms in determining human behavior. Overall, this commentary highlights the need to consider a more balanced perspective on the role of conscious and unconscious determinants of self-control in future research.

A large number of studies conducted in the last years have been exploiting the possibility of using online research tools instead of laboratory ones, as they guarantee easier and faster access to large groups of participants. However, the validity of such online instruments in consciousness studies is still a matter of scientific debate. In this framework, the article by Hirao et al. explores the reliability of online experiments for collecting data about perception and impressions of faces. To this aim, they conduct an experimental study with both a typical laboratory sample and two online samples. They compare the samples' responses regarding three visual perceptual features and 16 items regarding impressions of the face, such as trustworthiness, honesty, and attractiveness. Overall, they find a moderate to high correlation between the scores assessed in the online and in the in-person samples and a very limited rate of mismatch between the samples. However, they find that the differences in the average scores of the stimuli were smaller in the online assessment than in the laboratory one, suggesting the need for a larger sample while conducting online research. This article, then, is valuable in providing practical guidelines for future online studies investigating the perception and impression of faces.

Consciousness research makes large use of neuroimaging methods, as they can reveal how the brain works in different consciousness states and for elaborating different contents. This Research Topic includes three articles exploring the limits of the actual neuroscientific methods in consciousness studies and proposing new frameworks for their improved use. The first article by Koculak and Wierzchon presents a critical re-thinking about the use of the so-called "resting-state" paradigm, in which participants are scanned with an fMRI while not receiving any external stimulation and having no straightforward task. They argue that this paradigm, while extremely useful in the context of clinical application for the diagnostics of various disorders of consciousness, could be made more useful for a non-clinical scientific approach. In particular, they propose adding a type of experience sampling during the paradigm to connect neural activity and mental contents, and to mix the resting-state paradigm with tasks, as this would further increase the ecological validity of this assessment.

Investigations about the neural correlate of consciousness also employ the event-related potential (ERP) technique. Recently, it has been proposed that an early negative ERP component may reflect the awareness of stimuli, in terms of perceptual awareness negativity (PAN; Dembski et al., 2021). PAN has been extensively investigated by Koivisto and colleagues (Koivisto and Revonsuo, 2007, 2010; Koivisto and Grassini, 2016). Bola and Doradzinska critically review the evidence in favor of PAN as a marker of consciousness. In particular, as many contradicting results point out the possibility that PAN mostly reflects attentional processes rather than awareness, they question whether the "A in PAN indeed stands for awareness and not attention" (Bola and Doradzinska; p. 3). PAN shares several features with a typical attentional component such as the N2 posterior-contralateral (N2pc). Thus, the authors suggest investigating PAN using a more falsification-oriented approach, thus effectively dissociating attention from awareness. As this literature is in its infancy, we hope that this opinion article could inspire a new line of investigations in the search for the neural correlate of consciousness.

In their article, Paoletti et al. address the interesting problem of the electroencephalographic correlates of different levels of self-awareness. Starting from the definition of different levels of the self as represented as concentric circles, from a peripheral narrative self to a central state of overcoming the self (a third state proposed by the authors and characterized by a complete absence of any sense of self), Paoletti et al. propose a new hypothesis. They argue that "moving" toward the center of the model is related to a gradual slowing of the EEG frequencies associated with each state of the self. To support their hypothesis, they further review a number of EEG studies on different meditative states and their associated levels of self-awareness. From this mini-review, they report evidence consistent with their hypotheses, with slower EEG frequencies detected during non-dual (emptiness) meditation, a meditative practice aimed at experiencing a form of pure awareness or absence of the self, resembling the overcoming of the self state proposed by the authors. However, further studies should be conducted to test this hypothesis.

Conclusion

In conclusion, this collection addresses many fundamental issues that have emerged over the last few years in the quest to understand consciousness, including problems related to self-awareness and the implications of recent neuropsychological studies. Even if these articles open up more scientific questions than they answer, they can contribute to the debate around the methodological foundation of consciousness research. The epistemology of consciousness studies is still in search of clear definitions and methods (Harman, 1994), to which we hope to contribute with this Research Topic.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

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Commentary: Two Ways of Thinking About Self-Control

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Keywords: self-control, self-monitoring failures, ego-depletion, reflective and impulsive determinants, non-conscious self-control

INTRODUCTION

The basic premise of Vosgerau et al.'s (2020; henceforth VSH) article is one that few consumer behavior researchers and psychologists would debate: "self-control conflicts are subjective" and "not all consumers pursue the same superordinate long-term goals" (p. 187). While the dominant paradigm defines self-control as a consumer's choice to desist from hedonic consumption, VSH outline self-control failures as choices violating superordinate long-term goals (whether hedonic or utilitarian) that entail the anticipation of regret. Therefore, the central message of VSH's framework is that self-control does not require abstinence from pleasure (i.e., exerting self-control $\neq$ sacrificing pleasure). VSH also argue that this conceptualization is vital for the construct validity of self-control studies in consumer research.

This commentary agrees with the idea that the choice of hedonic consumption (e.g., chocolate cake) is not always equated with failures in self-control. In this regard, Moayery et al. (2019b) showed that if consumers do not endorse any standards regarding their diet, they might buy more unhealthy snacks even when enough self-regulatory resources are available. Similarly, it has been suggested that the desire for unhealthy food cannot be translated into temptation, unless the person follows a healthy diet (Hofmann and Kotabe, 2012). At the same time, in this paper, I wish to draw attention to three issues that help in making the distinction between the perspective presented by VSH and my perspective on self-control. These issues are self-monitoring failures, ego-depletion effects, and reflective and impulsive determinants of self-control. Therefore, building on VSH's framework, this commentary proposes an expanded, more inclusive perspective on self-control problems. In order to flesh out this idea, I attempt to (1) clarify that people often fail to detect a conflict of self-control because they fail to self-monitor, (2) challenge the idea that ego-depletion is not a real phenomenon, and (3) highlight the role of reflective and impulsive aspects of self-control. This commentary also discusses a direction for future studies with emphasis on non-conscious forms of self-control and some methodological considerations for measuring impulses.

SELF-MONITORING FAILURES

VSH's framework considers the concept of opposing preferences as the core idea of the definition of self-control (i.e., a conflict between co-existing selves). These preferences may vary over time, together with a lack of symmetry in their importance. Therefore, according to this framework, exerting self-control can be conceived as resolving a goal conflict (e.g., a health goal vs. immediate gratification) in service of superordinate long-term preferences. On the other hand, self-control failures are represented as yielding to temptation (i.e., the violation of superordinate long-term benefits) for which the consumer expects to feel regret. In the same vein, recent studies also provide evidence for a link between anticipated emotions and self-control judgments (Kotabe et al., 2019). However, this commentary wants to emphasize the fact that people are not always able to perceive self-control conflicts due to self-monitoring failures.

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Self-monitoring is one the major ingredients of self-control. This includes keeping track of one's responses and actions to compare the real situation of the self to one's goals and ideals (i.e., recognition of conflicts; Baumeister and Heatherton, 1996; Baumeister, 2002). Simply stated, self-monitoring is closely related to the identification of an incompatibility between the expected outcomes of acting based on desire and the person's value system and self-regulatory goal standards (Hofmann and Kotabe, 2012). Therefore, conflict monitoring can be deemed as a fundamental cognitive function supporting the process through which control is recruited (Yeung, 2014). In this regard, prior research has shown that self-monitoring is associated with a wide range of behaviors including improved weight management, healthy dietary change (see Spring et al., 2020), and spending behaviors (for a review, see Moayery et al., 2019a). Nevertheless, a person may temporarily fail to experience a self-control conflict (i.e., self-monitoring failure; Hofmann and Kotabe, 2012). Indeed, sometimes communication to the higher cognitive system (in the prefrontal cortex), which is linked to self-control, is blocked due to consumers' lack of attention, which means that goals are kept in the pre-conscious domain in this situation (Plassmann and Mormann, 2017). For example, Mr. A, who is having a dinner date at a restaurant, may see a piece of chocolate cake on the dessert menu and be aware that his health goal is to eat healthy foods. However, he might not be paying attention toward his goal, and hence the absence of communication with the higher cognitive systems that are linked to self-control (see Plassmann and Mormann, 2017). This lack of attention can be partially attributed to the fact people often track multiple goals at the same time (Fujita, 2011; Neal et al., 2017). For instance, Mr. A has to pay attention to his date (e.g., presenting himself in a favorable manner) as well as his eating behavior (e.g., to prevent overeating non-healthy foods) simultaneously (see Fujita, 2011).

EGO-DEPLETION EFFECTS

VSH discuss that it is difficult to draw a generalizable conclusion from the current predominant paradigm for studying self-control due to the application of ego-depletion effects. They doubt the existence of ego-depletion and claim that it may be arguable to conjecture on what caused the effects that were observed in current studies on self-control. They argue that ego-depletion might be a result of cognitive fatigue or type-I errors. Although this commentary concurs with VSH that there are several challenges and criticisms of ego-depletion (for reviews, see Englert, 2016; André et al., 2019; Alquist et al., 2020), it appears premature to dismiss the phenomenon because none of the critical evidence provides conclusive answers that ego-depletion does not exist (Friese et al., 2019). In fact, the application of the ego-depletion theory in everyday problems, across a variety of domains, has been tested successfully. These include impulse buying, alcohol consumption, eating behavior, self-protective behavior, logical thinking, making choices, sport and exercise behavior, and even math test performance (Muraven et al., 2005; Vohs, 2006; Hofmann et al., 2007; Vohs and Faber, 2007; Bertrams et al., 2016; Englert, 2016; Moayery et al., 2019b). These findings are in line with the basic premise of the strength model emphasizing that different tasks and functions use a global resource (i.e., relying on a domain-general resource), which can become depleted by successive attempts at self-regulation (Bertrams et al., 2016; Englert, 2016; Wagner and Heatherton, 2016; Baumeister and Vohs, 2018). According to this account, the depleted state results in impaired self-control task performance, the phenomenon known as ego-depletion (Hagger et al., 2010; Baumeister et al., 2018; Alquist et al., 2020).

This commentary assumes that the ambiguity associated with ego-depletion is related to the uncertainties regarding the underlying mechanism as well as the nature of this limited resource (see Hedgcock et al., 2012; Friese et al., 2019). To address this concern, ample research has documented the cognitive, psychological and neurological aspects of ego-depletion as supporting evidence for this phenomenon (for reviews, see Englert, 2016; Wagner and Heatherton, 2016). For instance, it has been demonstrated that self-regulatory resource depletion weakens some kinds of cognitive activities (e.g., complex thinking) which need active guidance by the self (Schmeichel et al., 2003). Interestingly, Vohs et al. (2011), in line with the limited-resource model (i.e., the strength model), showed that ego-depletion is not equivalent to fatigue. They concluded that the ego-depletion effect appears when there is a lack of self-regulatory capacity, which can be interpreted as the tiredness of the inner energy that regulates unwanted responses. Another study also empirically demonstrated that self-regulatory resource depletion reduces the activity of the right middle frontal gyrus (located in the dorsolateral prefrontal cortex; Hedgcock et al., 2012). To conclude, although this commentary agrees that the ego-depletion theory suffers from several shortcomings (see Friese et al., 2019), up until now, alternative explanations cannot provide a complete picture of the self-control issue without subtly reintroducing the idea of depleted energies (Baumeister and Vohs, 2018; Baumeister et al., 2018). For example, in a move toward a new perspective on the nature of effortful control, Baumeister and his colleagues have recently integrated the resource models with other alternative theoretical approaches (e.g., cost-benefit models; Alquist et al., 2020; see also André et al., 2019). This body of literature provides new insight into the true nature of the capacity or resource to exert effortful control and related fatigue-like effects.

REFLECTIVE AND IMPULSIVE DETERMINANTS OF SELF-CONTROL

It can be discussed that VSH's framework ignores reflective self-control conflicts due to overemphasizing consumption self-control (e.g., consumption of time, money, and food), which makes it difficult to generalize the model to other behavior domains with more serious consequences (see Lamberton, 2020). This commentary assumes that making deliberate judgments and evaluations, as well as suppressing impulses are executive functions of this higher-order mental operation, known as the "reflective system" (Hofmann et al., 2009). This reflective system can be dietary restraint standards concerning eating or purchasing snacks (Hofmann et al., 2007; Moayery et al., 2019b), reflective trust in close relationships (Murray et al., 2011), or action and coping plans in health care professional behavior (Presseau et al., 2014), etc.

Now imagine a conflict between Sally and her partner, Harry: Sally likes her house to be clean, but it is not one of Harry's priorities. While Sally needs Harry's help to achieve her goal of keeping things clean, asking him to cooperate means she is left vulnerable to his non-responsiveness. If Sally wants to ask for his help (i.e., ignoring her need to avoid his rejection), she needs to make sure that it is safe for her to depend on Harry to achieve her goals (Murray et al., 2011). Are deliberate or conscious expectations of partner caring (i.e., reflective trust) enough to govern self-protection in romantic relationships? According to Murray et al. (2011), impulsive trust (i.e., automatic evaluative associations to a partner) and reflective trust (i.e., relatively conscious) jointly regulate self-protection in close relationships. Applied to eating behavior, prior research has shown that the joint consideration of impulsive (e.g., an implicit measure) and reflective influences (e.g., dietary restraint), as well as self-regulatory resources may help to predict unhealthy snack intakes more accurately (Hofmann et al., 2007; Friese et al., 2008). This concurs with findings from other studies in a representative range of self-control domains including drinking, impulse buying, sexual interest behavior, and other social interactions (see Hofmann et al., 2009; Moayery et al., 2019b). Taken together, these results suggest that a joint function of reflective and impulsive mechanisms can predict most human behaviors, with special application to consumer and health psychology (Strack et al., 2006; Hofmann et al., 2008a). According to this logic, "when consumers' behavior is less a result of reflective inputs and more a result of impulse, the quality of their lives suffers" (Vohs, 2006, p. 220).

VSH have recently responded to comments stating that their conceptualization of self-control can accommodate reflective self-control conflicts (see Scopelliti et al., 2020). In my humble opinion, even if we accept this notion, their conceptualization of self-control is still mute regarding the impulsive aspect of the self-control problem. In fact, while one the main goals of consumer psychology is to provide insights into when and why consumer behavior is directed by impulsive vs. reflective determinants (Hofmann et al., 2008b), VSH focus solely on deliberate and largely controlled forms of behavior. This is based on the premise that people, in their everyday lives, often act impulsively in a way that is not necessarily consistent with their declared evaluations and goals (Friese et al., 2008).

RECOMMENDATIONS FOR FUTURE RESEARCH DIRECTIONS

Traditional research has defined self-control as the capacity of the individual to override or inhibit their competing urges, impulses, desires, and automatic or habitual responses (e.g., Muraven and Baumeister, 2000; Hagger et al., 2010). Thus, this body of literature has mostly attempted to uncover the capacity for effortful impulse inhibition, and hence has neglected automatic self-control modes (Hofmann et al., 2009; Fujita, 2011). In a somewhat different approach, VSH characterized self-control failure as a violation of superordinate long-term goals accompanied by anticipated regret. However, in my opinion, this conceptualization is also in line with the intentional notion of self-control, and hence misses the non-conscious (automated) form of self-control. Consequently, this commentary strongly recommends researchers to devote a proportionate amount of attention to non-conscious initiation of self-control including automatic goal pursuit (Bargh et al., 2001; see also Carnevale and Fujita, 2016), habitual regulatory processes, priming effects (Rebar et al., 2016), and even the effect of sleeping patterns on self-control (Williams and Poehlman, 2017). Interestingly, some researchers have even suggested that it would be more instructive to view unconscious forces as essential determinants of self-control, through which interventions can be devised that disturb the domination of impulses via habit creation or disturb the implicit associations between vice and positive affect (for a review, see Williams and Poehlman, 2017). For instance, there is evidence showing that environmental cues which are associated with motor inhibition (e.g., fearful facial expressions) can be applied to control unintentionally evoked impulses toward rewarding food objects (Veling et al., 2011). Nevertheless, this paper does not aim to underestimate controlled inputs in consumer behavior, given that both conscious and unconscious processes should be respected in consumer research (see Baumeister et al., 2017).

In addition, this paper shares VSH's general perspective that self-control researchers should ensure that participants truly experience self-control conflicts. To this end, VSH consider some crucial methodological implications to clarify how researchers can verify that participants experience self-control conflicts and how to assess them (e.g., doing pre-tests). They also highlight the role of anticipated regret as an essential indicator to correctly capture self-control conflicts and failures. However, this commentary argues that these methods do not explain how impulses emerge or how researchers can measure them. To address this issue, I encourage researchers to follow a growing body of psychological literature that aims to conceptualize self-control as a psychological process and not as a unitary phenomenon (Hofmann and Kotabe, 2012; Hofmann et al., 2012, 2014; Moayery et al., 2019a). More especially, this body of research aims to shed light on the underlying psychological process rather than focusing on the ultimate outcome variable (e.g., food consumption) (Hofmann et al., 2012, 2014). As a result, this stream of research provides a clear distinction between the strength of a given desire (i.e., impulses) and the capacity to control a desire (Hofmann et al., 2014). Interestingly, impulse formation is the starting point of this conceptualization of self-control. For instance, Moayery et al. (2019a) explained how impulses are driven by internal context (i.e., personality, homeostatic dysregulations, and habit) and external stimuli. Thus, this conceptualization provides opportunities for measuring impulses through self-report measures (e.g., Everyday Temptation Study) or implicit measures (Hofmann et al., 2012, 2014).

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The author confirms being the sole contributor of this work and has approved it for publication.

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METHODS
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Reliability of Online Surveys in Investigating Perceptions and Impressions of Faces

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Online experimental methods are used in psychological studies investigating the perceptions and impressions of facial photographs, even without substantial evidence supporting their reliability and validity. Although, the quality of visual stimuli is more difficult to control remotely, the methods might allow us to obtain a large amount of data. Then the statistical analysis of a larger volume of data may reduce errors and suggest significant difference in the stimuli. Therefore, we analyzed the reliability and validity of online surveys in investigating the perceptions (shine, red, and dark) and impressions (attractiveness, trustworthy, and so on) of facial photographs created from averaged faces with skin tones modified using computer graphics (CG). In this study, we conducted online (Online1) and laboratory experiments with well-controlled conditions (Control). For each experiment, 50 participants (men and women in Japan, age: 20–59 years) completed the same questionnaire regarding their impressions of the same 28 CG facial photographs. The results showed significant correlations between the two experiments for all 19 items in the questionnaire. SD in the Online1 compared to the Control from the stimuli and individual differences were 56–84 and 88–104% in each questionnaire items, respectively. Moreover, the rates of mismatching perceptual evaluations to the corresponding physical features demonstrated in the photographs were 4.9–9.7% on average in an additional online survey of another 2,000 participants (Online2). These results suggest that online surveys can be applied to experiments to investigate impressions from CG facial photographs instead of general laboratory experiment by obtaining an appropriate number of participants to offset larger statistical errors that may result from the increased noise in the data from conducting the experiment online.

Keywords: face, impression, survey, online, reliability – reproducibility of results

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INTRODUCTION

In studies of perception and impressions regarding faces, facial photographs have been used as stimuli in experiments that investigate visual illusions in facial perception (Baker et al., 2007; Matsushita et al., 2015) and the relationship between specific facial features and impressions of a person (Fink et al., 2006; Samson et al., 2010; Jaeger et al., 2018). In studies conducted in a laboratory, facial photographs are presented as printed media or on computer displays with controlled color and brightness and under well-controlled lighting conditions. This is because appropriate visual conditions of the stimuli are desirable for the participants to properly perceive their differences, reducing the noise in the evaluation.

With the widespread use of the Internet, online surveys allow participants to take part in research despite not being physically present in a laboratory. This is especially important advantage of online surveys during the current coronavirus pandemic as of course online surveys cut the risk of transmission of infectious disease. In online settings, the cost of recruiting participants and providing a suitable research location can be used to acquire a larger number of participants instead. Although, there is a potential disadvantage in this approach due to the increase the error in the evaluation of each stimulus (due to less control over visual stimuli among participants and the subsequent increase in individual differences.), the larger data sample may be an advantage in detecting evaluation differences within the stimuli because the SE is inversely proportional to the square of the sample size.

Some reports have investigated the reliability and validity of online surveys compared to their paper-based counterparts (Carrascosa et al., 2011) or compared to existing laboratory research (Crump et al., 2013) and the limitation of online versions (Alessi and Martin, 2010; Ball, 2019). For example, Crump et al. (2013) found that a variety of commonly used tasks performed online produced results broadly consistent with laboratory results. However, the validity and reliability of online surveys for investigating impressions from facial photographs remains unknown. This is important because, unlike linguistic stimuli, the subjective impression of a face photograph may change depending on conditions under which the photograph is viewed. For example, the radiance of a face can affect the impression of it (Ikeda et al., 2021). The radiance of the face can be affected by the room conditions and display screen conditions, neither of which can be controlled easily in an online experiment.

Therefore, we first investigated the difference between data from an online experiment (henceforth referred to as "Online1") and data from a typical experiment in a laboratory with well-controlled stimuli and experimental conditions, including lighting (henceforth referred to as "Control"). Specifically, the current study aimed to investigate the validity and reliability of an online survey of perception of and impressions formed by faces. We also attempted to calculate the necessary number of participants for an online survey if the same level of statistic reliability was required. In both experiments, 50 participants evaluated the same 28 computer graphics (CG) stimuli faces that varied by age, sex, and skin features. The faces were evaluated in 19 items of the questionnaire, which assessed the perceptual features and impressions using a five-point Likert scale. Then, the validity and reliability of the online surveys was evaluated by examining the correlations between the values evaluated in the two experiments. If the correlations of the data in online survey to a typical experiment in a laboratory with well-controlled stimuli are statistically significant, the online method could be regarded as valid because it suggests that online survey can provide the same data of evaluations. At the same time, the level of the contribution rates from the correlation analysis presented by the R^2 scores could suggest the reliability, which represents the stability of the results. Reliability in experimental data is not only dependent on the procedure to obtain the data but also the sample size because it is related to the statistical error. Therefore, based on the observed correlation coefficients, we can calculate the appropriate number of participants in a future online survey to maintain the same level of reliability based on the difference in the error due to the stimuli and the individual differences.

In addition, we also investigated the rates of mismatches in the physical features of the stimuli and the perceptual items. By examining these rates, it may be possible to find a limitation in the perception of the stimuli, which is dependent on the quality of the visual stimuli. As the number of participants in the Online1 ($n = 50$), was not expected to be sufficient for this purpose, we conducted an additional online experiment with 2,000 participants, constituting "Online2." Online2 used the same methods as the original online experiment. We compared the rates of mismatches for participants by age and sex. If the rates were high in a certain group of participants and in certain items in the questionnaire, this would suggest a limitation of online experimentation of this type.

MATERIALS AND METHODS

Participants

A total of 100 healthy men and women living in Japan [50 men and 50 women, mean age: 39.9 years (11.1 SD)] participated in Online1 and Control; a separate group of 2,000 healthy men and women living in Japan [1,000 men and 1,000 women, mean age: 40.0 years (11.0 SD)] participated in Online2. Each participant indicated no optical disorders by self-report before the experiment and owned a personal computer or a tablet computer, excluding mobile phones with a small display, to participate in this experiment in Online1 and Online2. Each participant provided informed consent to participate in the study. The Research Ethics Committee of the Shiseido Global Innovation Center approved this study, and all methods were conducted following approved guidelines.

Stimuli

Twenty-eight CG facial photographs were used as visual stimuli. These were divided into four groups according to age (20s vs. 40s) and sex (male vs. female). For each group of stimuli, there were seven photographs with different skin features (original averaged face, darker skin, brighter skin, redder skin, yellower skin, shiny skin, and matte skin). From eight facial photographs, four original averaged faces were created: Japanese men in their 20s, Japanese men in their 40s, Japanese women in their 20s, and Japanese women in their 40s. The darker and brighter faces were created from the original averaged face by making the skin tone darker or brighter by +2 or −2 SDs from L* on the cheek, based on the distribution of skin color from a previous experiment by the authors (unpublished). The red and yellow images were also created by adjusting the color of the original face to +2 SD or −2 SDs based on the a* and b* distributions for red and yellow, respectively, from the same study. The shiny and matte images were created by a professional CG creator who altered the contrast of the skin color. Photoshop CS4 (version 11; Adobe Inc., 2008) was used in the process of creating the stimuli (**Figure 1**).

Questionnaire

Questionnaire items included three perceptual features that used bipolar scales (dark–bright, red–yellow, and shiny–matte) and 16 items regarding impressions of the face measured using monopole scales (trustworthy, honest, reliable, confident, attractive, likable, healthy, youthful, clean-cut, want to be, cool, energetic, polished, beautiful, good at work, and unisex). We selected six items (trustworthy, honest, reliable, confident, attractive, and likable) from a previous study as the basic impressions from appearance (Jaeger et al., 2018) and added the other 10 items. All questionnaire items used a five-point Likert scale, with scores ranging from −2 to +2. For example, the dark–bright dipole scale appeared as follows (translated from the original Japanese): +2, "match to dark"; +1, "a slight match to dark"; 0, neutral; −1, "match to bright"; and −2, "a slight match to bright." The monopole scale categories appeared as follows: +2, "I think so very much"; +1, "I think so"; 0, neutral; −1, "I do not think so"; and −2, "I do not think so very much."

Procedure

This study included an online experiment (Online1) and an experiment using printed photographs in a laboratory (Control). In Online1, 50 participants looked at the stimuli on their personal computers or tablets and filled in the questionnaire at home. An in-house platform for online experiments was used. In the control condition, under well-controlled lighting, the other 50 participants were in the laboratory, looked at the same stimuli printed on paper (210 × 297 mm), and filled in the same questionnaire. In both of the experiments, participants filled in the list of three perceptual questionnaire items and the other 16 items of impressions after looking at one of visual stimuli at their own pace in a block. They repeated 28 blocks for each visual stimulus assigned to each of them. The orders of stimuli and the questionnaire items in each of perceptions and impressions were also randomized.

After the two experiments, we conducted an additional online experiment with additional participants using the same method as Online1, the 28 original stimuli, and the three perceptional items of the questionnaire; this constituted Online2. In the three experiments, the participants were divided into two groups. The first group evaluated 14 stimuli portraying males and females in their 20s, while the second group evaluated 14 stimuli portraying males and females in their 40s.

Statistical Analysis

The average scores for both Online1 and Control groups were calculated for each item. To investigate the validity of the Online1, the tests of significance were applied to Pearson's product-moment correlation coefficients for the 28 scores between the two experiments, with a criterion of $\alpha = 0.05$. Furthermore, the ratios of SDs of Online1 vs. Control conditions

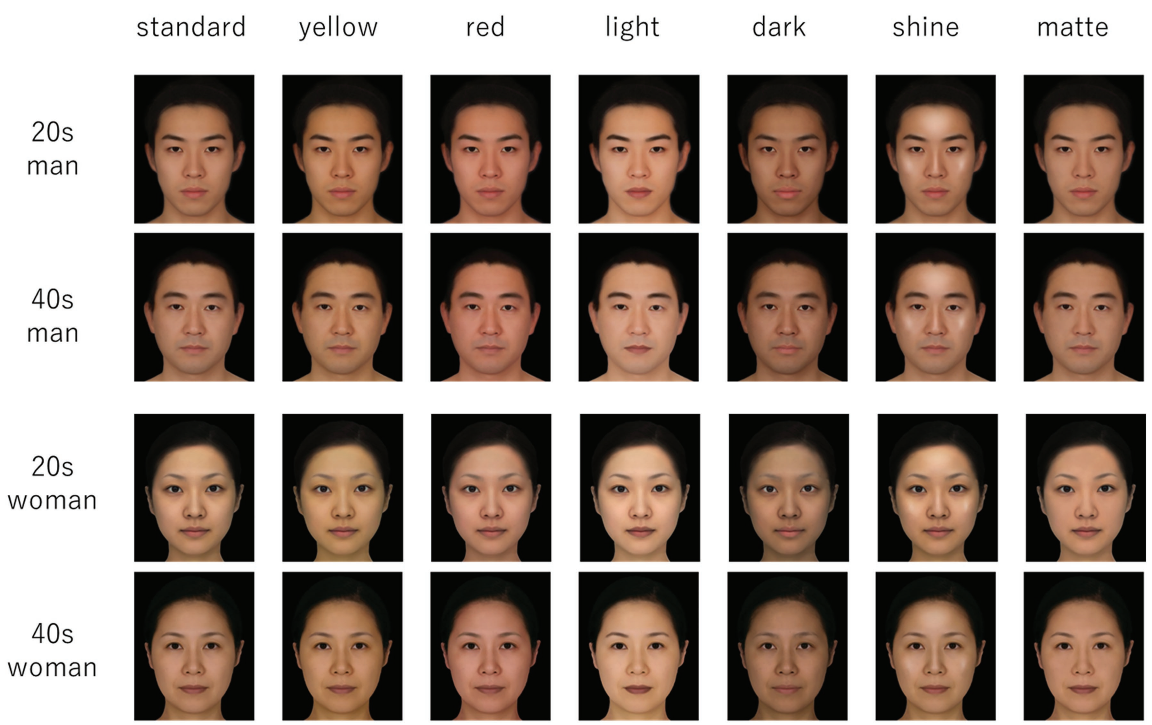

FIGURE 1 | Facial photographs used in both experiments.

were calculated both for the differences in the stimuli (a = ratio of the SDs of the scores averaged for the 28 stimuli for the 50 participants) and the individual participants (b = ratio of the averaged SDs of 28 stimuli for the 50 participants) to calculate the ratio of the required sample size in a future online experiment and match the effect sizes in the control using the formula b^2/a^2.

As for the analysis of Online2, the calculated total rates of mismatched answers between the physical features (e.g., the rate calculated from the number of participants who evaluated the CG face of dark skin brighter compared to the brighter skin CG face) were averaged for the four types of stimuli (CG facial photographs: darker skin vs. brighter skin, red skin vs. yellow skin, and shiny skin vs. matte skin). The values suggest how precisely participants perceive the optical features in the visual stimuli. The perceptual evaluations associated with items in the questionnaire (dark–bright, red–yellow, and shiny–matte) for each age group (20s, 30s, 40s, and 50s) and participant gender groups (male and female) were also calculated. The difference in the ratios among the groups was examined using the chi-square test ($\alpha = 0.05$).

RESULTS

Testing Validity

The validity of Online1 was tested by correlating the results with that of Control. The correlations of the tested items between Online1 and Control were statistically significant for all the 19 items ($p < 0.01$; **Table 1**; **Figure 2**), suggesting that Online1 result was valid.

Estimating Number of Participants Needed for Reliability

The ratio of the estimated participants in the online survey compared to the controlled experiments to maintain the same level of error was calculated by the formula b^2/a^2 for each questionnaire item. a was the ratios of SDs of the averaged scores for the 28 stimuli for the 50 participants for Online1 compared to Control. These ratios ranged from 56 to 84%. All 19 questionnaire items had significantly smaller SDs in Online1 than Control in the chi-square test ($\chi^2 = 19.0$, df = 1, $p < 0.001$). b was the ratio of average SDs of the 28 stimuli for the 50 participants for Online1 compared to Control. These ratios ranged from 88 to 104%. Also, the number of questionnaire items with a smaller average SD in the Online1 was 15 of 19, which was statistically significant in the chi-square test ($\chi^2 = 6.37$, df = 1, $p = 0.012$; **Table 1**). The values of b^2/a^2 ranged from 1.3 to 2.6 for each item, suggesting that online experiments may need 1.3–2.6 times the number of participants to obtain a comparable result as a laboratory experiment.

Mismatched Answers Between the Physical Features

Moreover, we investigated the differences in the mismatch rates of perceptions within the participant groups to investigate whether there are any limitations in a specific category of participants. The values of the mismatch rates suggest the rates of participants who did not perceive and evaluate the physical features of stimuli precisely. In the results from Online2, the rates of mismatch between the physical features

TABLE 1 | Correlations and differences of errors for each item for the Online1 and Control conditions.

Questionnaire items		Correlation between online and control	SD calculated from averaged scores of 28 stimuli			Averaged score of 28 stimuli SDs of 50 participants		
		R^2	Online1	Control	Ratio (O/C)	Online1	Control	Ratio (O/C)
Perception	Shine	0.951*	0.523	0.710	73.7%	0.884	0.945	93.6%
	Red	0.931*	0.506	0.701	72.1%	0.819	0.910	90.0%
	Dark	0.911*	0.568	0.808	70.2%	0.895	0.949	94.3%
Impression	Clean-cut	0.742*	0.345	0.489	70.5%	0.859	0.857	100.2%
	Like	0.731*	0.265	0.463	57.2%	0.854	0.965	88.5%
	Want to be	0.707*	0.249	0.446	55.7%	0.908	0.980	92.7%
	Attractiveness	0.678*	0.250	0.444	56.4%	0.847	0.926	91.5%
	Good at work	0.647*	0.263	0.349	75.4%	0.849	0.813	104.4%
	Beautiful	0.646*	0.309	0.520	59.4%	0.894	0.919	97.2%
	Honest	0.637*	0.274	0.376	73.0%	0.850	0.815	104.2%
	Trustworthy	0.615*	0.269	0.359	74.9%	0.827	0.790	104.8%
	Youthful	0.614*	0.276	0.405	68.0%	0.897	0.927	96.7%
	Cool	0.554*	0.192	0.293	65.6%	0.843	0.940	89.7%
	Polished	0.532*	0.267	0.437	61.1%	0.836	0.891	93.8%
	Healthy	0.496*	0.277	0.381	72.7%	0.893	0.978	91.3%
	Reliable	0.483*	0.264	0.314	84.1%	0.845	0.888	95.2%
	Unisex	0.326*	0.185	0.351	52.7%	0.867	0.958	90.5%
	Confident	0.289*	0.259	0.343	75.7%	0.840	0.909	92.3%
	Energetic	0.240*	0.226	0.325	69.4%	0.836	1.014	82.4%

*$p < 0.01$.
O/C: ratios of the Online1 to the Control.

(darker skin vs. brighter skin, red skin vs. yellow skin, and shiny skin vs. matte skin) and the evaluations (dark–bright, red–yellow, and shiny–matte) were 4.9, 5.9, and 9.3%, respectively (**Table 2**). The differences within the four age groups regarding the mismatch rate were not significant according to the chi-square tests for the three questionnaire items. However, the difference between the male and female participants for the "shiny skin vs. matte skin" item was statistically significant for the chi-square test ($\chi^2 = 12.10$, df = 1, $p < 0.001$; **Table 2**). The difference may suggest a limitation in the reliability of the data in specific segments of the participants.

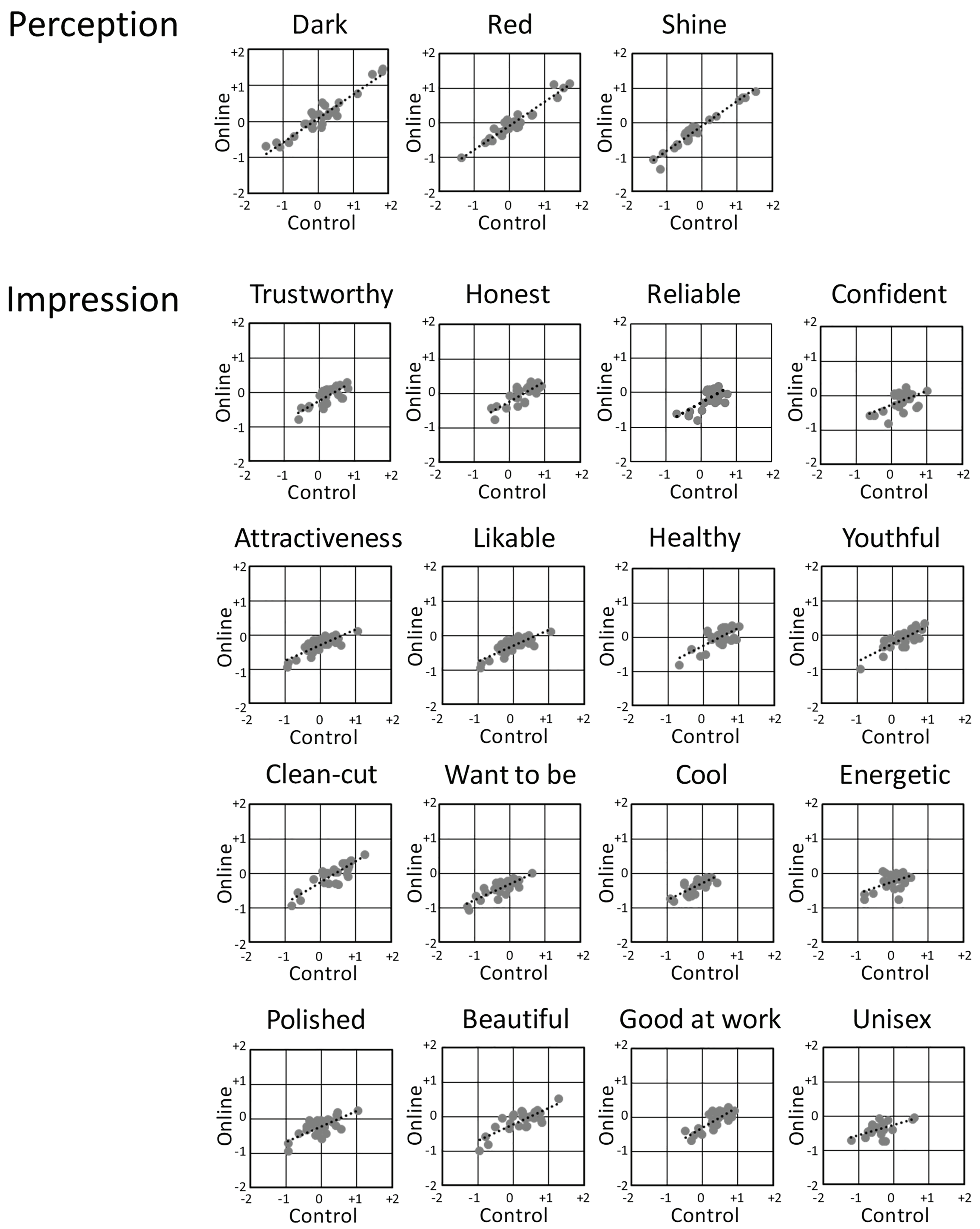

FIGURE 2 | Correlation between the Online1 and Control averaged scores for each questionnaire item for 28 stimuli.

TABLE 2 | The rates of inversely matching physical features to perceptual evaluations in the Online2.

Matching of stimuli features and answers		Participant characteristics						
	Age and sex groups	**20s**	**30s**	**40s**	**50s**	**Male**	**Female**	**Total**
	Number of participants	**500**	**500**	**500**	**500**	**1,000**	**1,000**	**2,000**
Dark vs. Bright	Did not evaluate the dark item as darker rather than brighter	5.0%	5.6%	3.9%	5.2%	5.5%	4.4%	4.9%
	Evaluated the image as equally dark and bright	13.2%	13.8%	11.6%	15.2%	14.3%	12.6%	13.5%
	Evaluated the dark item as darker rather than brighter	81.8%	80.6%	84.5%	79.6%	80.2%	83.1%	81.6%
Red vs. Yellow	Did not evaluate the red item as redder than yellower	5.6%	6.4%	5.5%	6.0%	6.5%	5.3%	5.9%
	Evaluated the image as equally red and yellow	20.3%	21.5%	21.0%	23.4%	22.9%	20.3%	21.6%
	Evaluated the red item as redder than the yellower	74.1%	72.1%	73.5%	70.6%	70.7%	74.5%	72.6%
Shiny vs. Matte	Did not evaluate the shine item as shiner than matter	10.0%	9.6%	9.5%	8.0%	11.0%	7.6%	9.3%
	Evaluated the image as equally shiny and matte	20.8%	25.1%	23.7%	26.0%	27.5%	20.3%	23.9%
	Evaluated the shine item shiner than matter	69.2%	65.3%	66.8%	66.0%	61.6%	72.1%	66.8%

DISCUSSION

In the current study, we investigated the reliability and validity of an online survey of perceptions and impressions of faces, by examining correlations between face evaluations obtained in an online survey (Online1) with face evaluations obtained in a well-controlled laboratory setting (Control), and estimating the number of participants needed for to maintain reliability and examining mismatch rates of perceptions in a larger online survey (Online2). We found positive correlations between Online1 and control experimental data for all the questionnaire items, suggesting that online survey is valid, but that the number of participants needed is 1.3–2.6 times that of a laboratory survey. In addition, there were generally low rates of mismatch.

The positive correlations suggest that the online survey and the general laboratory survey produced comparable results. The values of R^2 between the Online1 and Control suggested moderate or low correlations for the items regarding impression (0.240–0.742) compared to items regarding perceptions (0.911–0.951). Nonetheless, because values of R^2 are dependent on SDs in the differences of the stimuli, which, even in the general survey, were smaller for the items of impressions based on the perceptions in the information processing than the evaluation of the perceptions themselves. These results support the validity of online surveys.

Regarding reliability, the differences in the average scores of the stimuli were smaller in the online than in the control group for all items. This suggests that the online survey requires a larger sample size than the traditional, well-controlled lab-based survey. The required online sample size was estimated to be 1.3–2.6 times larger compared to the control based on the difference of errors within the two methods from the differences of stimuli and individual differences; these values may vary based on additional data and may depend on specific methods. Namely, differences in the stimuli were difficult to observe because of difficulty controlling the quality of visual stimuli in an online survey; however, this can be partially overcome by increasing the sample size.

The mismatching rates found in Online2 were less than 10% suggesting that participants had no difficulty in perceiving the online face stimuli. However, the mismatch rate between men and women was different for the item regarding shiny–matte skin. It is unclear however, if this mismatch rate difference indicates a genuine sex based difference in perception of the shiny/matte appearance of online face photographs or simply a difference in understanding of the meanings of the words in the participant segments, which may be the case in the original Japanese word used for shiny.

In other words, the current study overall supports the use of online surveys for testing the perception and impressions of face stimuli. However, it should be noted, that differences in the results of online and laboratory surveys may arise depending on the method used to recruit participants and several other factors, including their subsequent comprehension of the survey, possible deception in their answers, and communication with the researchers (Zhou and Fishbach, 2016). Online surveys using visual stimuli can also be limited by the characteristics of devices used by participants; device type should thus be considered carefully, especially in experiments using a between-subject design. Although, the types of devices used were limited to personal and tablet computers in the current surveys, the differences between groups in the scores might also be influenced by the bias of the device types used within specific consumer segments.

In addition, in the current study all participants were Japanese and evaluated CG Japanese faces. Though, we found no evidence that the different skin colors were affected differently by the lack of control over e.g., room brightness in the online tests, further research is needed to determine if this can be generalized to more diverse groups of participants and face stimuli.

The results in the current study suggest that online surveys can be applied to experiments to investigate impressions from CG facial photographs instead of general laboratory experiment, with the caveat that the number of participants should be increased. Although, there are some potential limitations in online surveys, they may potentially play a significant role as a substitute for laboratory experiments regarding the perception of faces. The benefits may outweigh the potential limitations especially during the current pandemic. The current study adds to the growing list of reports in behavioral science (Chesney et al., 2009; Crump et al., 2013; Hergueux and Jacquemet, 2015) and psychophysics (Semmelmann and Weigelt, 2017) that support the use of online experimental methods. Online surveys appear to be an effective method for investigating the perception and impression of faces using photographs.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available due to confidentiality agreements with the participants; the data in this study are available only at the Shiseido Global Innovation Center. Requests to access the datasets should be directed to naoyasu.hirao@shiseido.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Research Ethics Committee of the Shiseido Global Innovation Center. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NH, KK, HI, and HO contributed to conception design of the study. NH and KK performed the statistical analysis. NH wrote the first draft of the manuscript by the support of HI. HO checked and revised the manuscript as the senior author. All authors contributed to the article and approved the submitted version.

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OPINION
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Perceptual Awareness Negativity—Does It Reflect Awareness or Attention?

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Keywords: consciousness, attention, ERP, awareness, visual perception

INTRODUCTION

Identifying the neural correlates of consciousness (NCC) is one of the most important endeavors in neuroscience. A key debate concerns the question whether conscious experience is generated by the early activity of the sensory cortex, or rather by later activity of the supra-modal parietal and frontal cortices. Initial research using the event-related potentials (ERP) technique supported the "late" view, with many studies concluding that the P3b ERP component - a positive wave occurring over centro-parietal regions around 300–500 ms after the stimulus - reflects the mechanism of consciousness (review: Dehaene and Changeux, 2011). However, more recent work reveals, first, that some clearly perceived stimuli do not evoke P3b, meaning this component is not necessary for consciousness; and second, that P3b can be evoked or modulated by subliminal stimuli, which indicates it is not sufficient either. Along with this evidence challenging P3b as NCC, several lines of research have provided strong support for the "early" view. Specifically, a growing body of evidence shows that becoming aware of a stimulus is reliably associated with a negative-going ERP component observed as early as 150–250 ms after the stimulus onset over the modality-specific sensory regions. Such awareness-related negative components have been found in visual, auditory, and somatosensory modalities, and therefore an overarching term Perceptual Awareness Negativity (PAN) has been recently proposed (Dembski et al., 2021).

Recent progress in investigating the mechanisms of perceptual awareness using ERPs has been reviewed by Förster et al. (2020) and Dembski et al. (2021). Both reviews argue that there is enough evidence to falsify P3b as a marker of consciousness, and conclude that PAN is at present the best candidate for NCC. While we generally agree with their view, in this opinion piece we point out that a key challenge faced by the proponents of early NCC is disentangling mechanisms of consciousness from mechanisms of attention. Assuming that PAN reflects the phenomenal aspect of consciousness (Koivisto et al., 2017; Derda et al., 2019), which is by definition orthogonal to attention (Lamme, 2003), dissociating ERP correlates of both processes should be in principle possible. However, we think that conclusive evidence for such a dissociation has not been provided so far and, what is more, a body of data suggests PAN might be in fact closely related to attention.

ERP MARKERS OF AWARENESS AND ATTENTION

Neural mechanisms of spatial and feature-based attention share many similarities with the postulated early NCC - both are rapid, often automatic, and operate in the sensory cortex *via* feedback connections (Koch and Tsuchiya, 2007; Moore and Zirnsak, 2017). In fact, electrophysiological research has consistently shown that allocating visual attention to a given stimulus is reflected by a more negative component detected at the parieto-occipital electrodes

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around 200 ms after the stimulus (*selection negativity,* SN; Harter and Aine, 1984), which is particularly prominent contralaterally to the stimulus presentation (*N2 posterior-contralateral*, N2pc; Eimer, 1996). Thus, both visual PAN and attention-related negativity are detected at the same electrodes and in the same time-window, and both are most prominent in the contralateral hemisphere - the only difference is that PAN is defined in relation to activity evoked by unconscious stimuli, while attention-related components in relation to the activity evoked by task-irrelevant stimuli (i.e., presented in irrelevant locations or lacking relevant features). But the fact that these components are defined in relation to a different baseline does not preclude that they are generated by the same source and reflect the same underlying process.

The relation between feature-based attention and early NCC has been investigated by several studies. In the early work of Koivisto et al. PAN was repeatedly observed in response to all aware stimuli - both task-relevant targets and task-irrelevant distractors - irrespective of their status (Koivisto et al., 2005, 2006, 2009; Koivisto and Revonsuo, 2007). These observations suggested that PAN is encapsulated from the influence of feature-based attention and the cognitive aspects of processing, and thus taken as evidence that it represents phenomenal awareness. However, we think these conclusions should be treated with caution as, first, the discussed studies tested small groups of participants by today's standard (between 10 and 12); and second, on a non-significant ANOVA interaction (between stimulus relevance and awareness), whereas such absence of evidence cannot be treated as evidence of no effect (Wagenmakers et al., 2018). More recent studies reported that PAN is indeed evoked by task-irrelevant distractors, in line with results of Koivisto and colleagues; but found also that task-relevant stimuli evoke PAN of significantly greater amplitude than the task-irrelevant ones (Pitts et al., 2014; Shafto and Pitts, 2015; Schelonka et al., 2017). This strongly suggests that PAN is influenced by the task-related factors, and thus challenges earlier conclusions of Koivisto et al. (2005, 2006, 2009). Yet, it is worth emphasizing that some early studies observed differences in the spatio-temporal profiles of awareness- and attention-related early ERP effects (Koivisto et al., 2005; Koivisto and Revonsuo, 2007). Thus, in such a scenario greater PAN to task-relevant stimuli will reflect an overlap of two independent components [as discussed by Pitts et al. (2014)]. Therefore, the putative functional dissociation of awareness and feature-based attention should be the focus of future studies.

In another study Koivisto et al. (2009) investigated how PAN interacts with the top-down spatial attention. Stimuli were displayed either in the attended or in the unattended visual field, and participants were either aware or unaware of their presentation. Quite strikingly, clearly visible stimuli did not evoke PAN when displayed in the unattended visual field. This result is in line with an earlier study, in which PAN was greatly reduced in a passive viewing condition, which did not require focused attention (Koivisto and Revonsuo, 2008). While these findings might indicate that attention is a prerequisite of consciousness, as argued by Koivisto et al. (2009), such an interpretation will be difficult to reconcile with the assumption that PAN reflects an elementary phenomenal experience (e.g., Koivisto et al., 2017). Because implications of the Koivisto et al. (2009) study are of crucial importance, we argue that the relation between spatial attention and early NCC should be further investigated.

While so far we have discussed to what extent PAN is influenced by the top-down feature-based or spatial attention, another question is whether the same type of activity can be evoked by unconscious stimuli that are salient or task-relevant. This question is of particular importance, since the attention-related early negative components can be evoked by unconscious stimuli (Koivisto and Revonsuo, 2007; Travis et al., 2019; Bola et al., 2021). But finding that PAN can be evoked or modulated unconsciously would falsify this component as an NCC (similarly to P3b; Silverstein et al., 2015; Doradzińska et al., 2020) and might suggest it is more closely related to attentional prioritization. It is thus important to point out that Koivisto and Grassini (2016) found that unaware but correct trials - those in which participants reported not seeing a stimulus but provided a correct response in a forced-choice task - were characterized by more negative amplitude in the PAN spatio-temporal window, in comparison to unaware and incorrect trials. They interpreted this effect as reflecting residual awareness in the "unaware" but correct trials, not reported by some participants due to a conservative bias. But an equally likely interpretation is that PAN might reflect greater involvement of attention and more extensive processing in some of the unaware trials, and thus that it can be evoked outside of awareness. Of note, a similar effect has been observed by Eklund and Wiens (2018; see their Figure 2), but it was not analyzed statistically[1]. We understand that the main argument against our reasoning might be as follows: *PAN is defined as a difference between aware and unaware presentations, and thus there is no such thing as an "unconscious PAN"*; but we again emphasize, that such a definition does not preclude the very same type of activity that constitutes PAN to be related to other mechanisms and thus be observed in other comparisons. Testing this possibility will be crucial for establishing PAN as NCC. Therefore, future research should identify the sources or spatio-temporal filters representing PAN according to the classic definition (i.e., comparison between aware and unaware trials) and then apply them to compare activity observed in the unconscious conditions, for instance evoked by salient and neutral subliminal stimuli. Such a research strategy will allow determining whether the "PAN-like" negativity seen in the unconscious trials reflects the same process as the classically defined PAN.

Importantly, while results discussed so far cast doubt on the function of PAN as a marker of awareness, the exact function of attention-related components is also a matter of

[1]Interestingly, PAN differed between correct and incorrect unaware trials in studies of Koivisto and Grassini (2016) and Eklund and Wiens (2018), in which stimuli were presented centrally (always in the same location); but not in the studies of Lamy et al. (2009) and Salti et al. (2012), in which stimuli were presented in one of the uncued peripheral locations. Our putative interpretation is that in the latter studies the top-down spatial attention was not sufficiently involved and therefore PAN was not observed [in line with results of the Koivisto et al. (2009) study, discussed in the previous paragraph].

debate. For instance, while N2pc is classically interpreted as reflecting attention shifts, robust N2pc has been repeatedly observed without an accompanying behavioral effect of attention (Kappenman et al., 2014). Further, N2pc is unaffected by attentional cueing - its amplitude is the same in response to stimuli presented in the cued and uncued locations (Brisson and Jolicoeur, 2008; Kiss et al., 2008). Both findings suggest a possibility that N2pc does not reflect attention shifts *per se*, but rather a different, co-occurring process. In line with this hypothesis, recent data indicates that N2pc might rather represent engagement of attention in binding and integration of features (Zivony et al., 2018). Indeed, in a change blindness study PAN was related to a mere detection that something has changed, while N2pc occurred only when subjects were able to identify a change (Busch et al., 2010). If N2pc is indeed a marker of binding and integration of information then many electrophysiological findings interpreted as reflecting mechanisms of attention might, in some way, be more closely related to the mechanism of consciousness (Mudrik et al., 2014).

Finally, while in this commentary we focus on discussing attention and consciousness in the visual domain, one of the key arguments of Dembski et al. (2021) is that PAN is common across modalities - visual, auditory, and somatosensory - and can be observed in respective sensory cortices. Here we want to emphasize two points. First, because the attention-related negativity occurs also in the auditory domain (Alho et al., 1987; Gamble and Luck, 2011; Luck and Kappenman, 2012), the discussed relation between neural correlates of attention and consciousness should be investigated also in the auditory, and in other modalities. Second, the modality-specific neural mechanisms are expected for attention, the role of which is to prioritize stimuli from a particular modality. But in case NCC a mechanism integrating these unimodal experiences into a supra-modal, coherent, and unified conscious experience must be proposed (Mudrik et al., 2014). Because such a mechanism has so far not been proposed or investigated in the context of PAN, this might be considered a theoretical argument against early NCC in general, and PAN in particular.

CONCLUSIONS

Förster et al. (2020) and Dembski et al. (2021) provided a detailed overview of the recent electrophysiological research on NCC. Both reviews concluded that a robust body of evidence supports the early Perceptual Awareness Negativity (PAN) as an ERP correlate of consciousness. While we agree that PAN is at present the most promising candidate for NCC, in this opinion article we have discussed evidence indicating that PAN might be closely related to mechanisms of attention. Relevant data is at present scarce, but there is evidence indacting PAN is not necessary for consciousness (Koivisto et al., 2009), and that it might not be sufficient either (Koivisto and Grassini, 2016; Eklund and Wiens, 2018). These effects have so far not been discussed critically but, if further confirmed, they might challenge the dominant interpretation of PAN as a correlate of phenomenal awareness. Therefore, an important message of the present article is that a falsification-based approach should be more often embraced when investigating PAN, similarly as has been done in case of P3b.

In conclusion, while proponents of the "early" view have falsified the P3b component as an NCC by showing that it reflects mainly task-related cognitive processing, they now face a challenge of proving that "A" in PAN indeed stands for awareness and not attention.

AUTHOR CONTRIBUTIONS

MB and ŁD discussed the presented ideas. MB drafted the initial version. All authors revised the manuscript.

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Consciousness Science Needs Some Rest: How to Use Resting-State Paradigm to Improve Theories and Measures of Consciousness

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INTRODUCTION

The discovery of a brain network that is systematically deactivated during task execution while staying active when participants have no task to perform has instigated a new area of studies (default mode network; Raichle et al., 2001). It also imposed on neuroscience a particular dichotomous view of brain activity seen as the constant transitions between a reflexive mode (captured as the neural activity during a task) and a default mode (reflecting intrinsic brain activity; Callard and Margulies, 2011). The first can be studied with various cognitive tasks. The second is most pronounced when the participants are not receiving any external stimulation and have no straightforward task. This so-called "resting-state" (RS) paradigm became the most widely used method to capture the intrinsic, default activity of the brain. It is often treated as a baseline condition (Gusnard and Raichle, 2001) with which the task activity can be contrasted, revealing neural activity related to particular cognitive tasks. Over the years, the notion of the opposition of intrinsic and task activities (Cole et al., 2014) and the concept of baseline activity (Morcom and Fletcher, 2007) received a significant amount of criticism. However, the RS is still used throughout neuroscience, in a mostly unchanged form since its introduction. Recently, some researchers (Finn, 2021) argued that the way we collect RS data should be improved. It was also argued that they should be combined with a task to reflect the more nuanced and complex nature of brain activity.

Here, we would like to discuss the importance of those recent works for the neuroscience of consciousness. Similar to other subfields, the above-mentioned dichotomous view of brain activity is also present in many studies on consciousness. The RS paradigm is primarily used in studies investigating the states of consciousness. It is treated as a baseline condition for comparing the activity in, for example, the disorders of consciousness (Hannawi et al., 2015), sleep (Tagliazucchi and Laufs, 2014), or anesthesia (Boveroux et al., 2010). This approach is consistent with the view treating RS activity as a measure of wakefulness (or general excitability of the brain). This view drastically limits RS usefulness, seeing it as a minimal but insufficient prerequisite for conscious processing. Here, we argue that the new reformative methodological approach (Finn, 2021) can be conceptually applied to consciousness research so as to allow for a better understanding of its neuronal underpinnings, especially in the emerging field investigating the relations between its states and contents (Bachmann and Hudetz, 2014). We also propose how such an improved RS paradigm should look like and how it may benefit the scientific study of consciousness.

CONSCIOUSNESS AT REST

The RS already proved itself useful in consciousness research, for example, improving the diagnostics of various disorders of consciousness (Bai et al., 2017). This success stems directly from the design of the RS paradigm. At the minimal level, it only requires some neuroimaging apparatuses as no stimulation is presented to the participant. It can be administered for long periods of time without much fatigue, allowing for a more thorough assessment (which can be crucial for diagnosing, e.g., epileptic seizures). Finally. it does not require any involvement from the participant who, depending on the situation, might not be able to properly perceive stimulation or provide a response. This restrictive approach minimizes the complexity of the procedure, yielding more robust results and making it more convenient in clinical settings.

This method is, however, usually transferred directly into non-clinical settings, where there is little practical necessity for such minimal procedures, except the convenience for researchers. While it might not have much consequence when investigating, for example, the connectivity of particular brain regions, in the case of consciousness research, it can very well-obstruct more than it is revealing. Firstly, we should consider what aspect of consciousness we can capture this way. In a clinical setting, the focus is on distinguishing between the states of consciousness and unconsciousness. Assuming that this disposition is relatively stable in time, researchers test a variety of characteristics through the calculation of single-digit outcomes averaged across the whole recording (Sitt et al., 2014). These outcomes are then used to classify patients as conscious or unconscious. However, when testing healthy awake participants, the variability in the signal cannot reflect a wakefulness or consciousness state but arises primarily from the conscious content present in their minds. Even if the RS session is short, this content will fluctuate significantly during this time, especially since no explicit task is given. Therefore, running a minimal RS procedure and averaging the results over the whole sessions blur content-related correlates and exaggerates unrelated to the consciousness differences between the participants. From this perspective, it seems crucial for consciousness research to stop ignoring this subjective variability. It appears that the easiest way to start is to ask the participants about it (Gonzalez-Castillo et al., 2021). This simple idea can result in many useful approaches, some of which we will point out in the next section.

The second troubling assumption implicitly included in the classical RS approach is that an acquired signal represents a typical spontaneous activity. However, the whole situation of a scientific experiment is undoubtedly very far from everyday life. Participants are usually confined in a small space of an experimental booth or MRI machine with dimmed lights and an explicit instruction to "not think about anything in particular." This is a very artificial setting compared to everyday life. For a long time, we knew of such specific influences (e.g., experimenter effect; Rosenthal, 1976) and it seems reasonable to assume that this effect influences brain activity in the same way as behavior. This could not only alter the pattern of spontaneous thought that the participants usually experience (e.g., focusing on the novelty or oddness of the situation) but also influence the correlates of wakefulness (e.g., increasing the level of stress related to taking part in an experiment). Introducing an RS that more closely resembles everyday life activities could help to verify the generalizability of already established markers and test to what degree they depend on the factors not related to consciousness.

The final troubling implicit assumption is treating rest and task as exclusive modes of operation. An RS procedure is a form of a task just by the virtue of being a part of an experiment. Conversely, assuming that all changes in the signal during a task are related only to how it is constructed significantly limits our inferences. This can be observed in the research on the neural correlates of consciousness, where the trials with weak or absent stimuli are usually labeled as unconscious (Silverstein et al., 2015). However, it is safe to assume that the participants were in fact conscious of many things (the screen, their bodies, etc.), not just the stimulus. Experiments are constructed to keep external conditions maximally constant, but the internal conditions, which most certainly vary, typically go unaccounted for. Extending the definition of rest to all the activities that are not directly influenced by the experimental manipulation, we can imagine how this background activity could behave similarly to an explicit RS procedure. These background-conscious contents are also likely to fluctuate and change, interacting with task-related processes without researcher control. The averaged evoked activity would then present a false image of stable markers that might replicate poorly in different conditions or with different individuals. The inclusion of the non-task signal into the analysis could at least account for those changes.

MAKING REST MORE USEFUL

We believe that analyzing an RS activity is a necessary element to capture the phenomenon of consciousness in its entirety. Currently, however, resting procedures are mostly done with the minimal clinical approach mentioned earlier. Therefore, unlocking its full potential will not only require to introduce more complexity to its design, which will inevitably make the analyses more difficult, but it will also allow for more informed inferences about the underlying mechanisms.

The most straightforward improvement is the inclusion of some form of experience sampling (Martinon et al., 2019). By simply asking the participants what they did during the resting period, we could account for the different thought patterns that a participant might have when being prompted to wait and "do nothing." Inevitably, people will vary greatly in the content of their thoughts. Depending on the form of the RS procedure and goal of the researchers, there are different ways that this could be done. When the main focus of an experiment are the spontaneous thoughts and their dynamics, an occasional prompt asking for the content of thought might be a viable option (e.g., Hurlburt and Akhter, 2006). When only a general type of the thoughts during resting is of interest, a questionnaire (e.g., Amsterdam Resting State Questionnaire; Diaz et al., 2014) at the end might give the researchers enough information. In fact, self-reports seem to be reliably related to the activity of major brain networks (Stoffers et al., 2015). Most importantly, this augmentation allows for tracking the correlates of spontaneous conscious thought on top of the markers of excitability.

Another enhancement is a more ecological approach to RS sessions. Instead of maximally reducing the external stimulation, researchers can incorporate settings resembling the natural human environment (Sonkusare et al., 2019). This can be achieved by the passive experiencing of audiovisual material (Naci et al., 2014), usage of more immersive technologies like virtual reality (Baumgartner et al., 2006), or recording resting data outside of the laboratory (Edwards and Trujillo, 2021). Not only would it bring the brain's activity closer to what is actually going on most of the day; it would also impose some level of constraint on the spontaneous thought. Humans evolved to function in a certain environment, the elements of which naturally capture attention and invoke certain cognitive processes. From this perspective, unconstrained spontaneous thought is also not something that happens often. Therefore, by introducing stimulation to a session, we can measure a structured version of RS, where the order of cognitive processes is dictated from the outside (Hasson et al., 2004), rather than reconstructed through experience sampling. Some researchers already tried this, for example, by *post-hoc* analyzing task data in a continuous fashion (Sitt et al., 2014), but most of its potential is yet to be explored.

Finally, following the aforementioned principles, one could introduce paradigms combining the RS with a task. Such integrated designs would allow us to investigate the relation between the conscious task-related content with the state. There is already a substantive literature on how the pre-stimulus activity influences conscious perception (e.g., Benwell et al., 2017; Samaha et al., 2017). Similarly, we could also look for stimulus-related patterns that reverberate in a non-task activity after its presentation. For example, through introducing randomly short breaks between stimuli, we could investigate if and how stimulation influences the background activity or even sample experience to get reports on fatigue, engagement, and other potentially important factors (Thompson et al., 2013). On top of that, as acknowledged by Finn (2021), in principle, there is no reason to not analyze task data with methods devised for the RS. Analyzing task data using RS methods might be more demanding than evoked activity analyses, but it could bring an important insight into conscious brain activity that is being overlooked.

CHALLENGES

The main methodological challenge we see is the necessity to rework both experimental paradigms and analysis pipelines. This might be difficult since most studies rely on evoked activity and model only the stimulus-related conscious activity of the brain. As mentioned in the previous section, we think that employing a mixed resting-task approach could be a good first step to recognize the most promising aspects of the data, for which new more sophisticated paradigms and analyses methods could be devised.

We also acknowledge that currently, there are significant theoretical obstacles for incorporating RS analyses. Most of the prominent theories of consciousness were constructed and validated through experiments involving tasks and stimuli-evoked activity. Therefore, it is difficult to formulate any testable hypotheses based on them, making the use of RS procedures troublesome. It seems that for now, only few (e.g., Tononi et al., 2016; Bachmann et al., 2020) could provide any predictions. Yet, we are convinced that this not only poses a challenge for current theories but also gives an opportunity for broadening their scope to more fully describe consciousness and the mechanisms that govern it.

CONCLUSIONS

In this opinion paper, we advocated for the greater use of the RS paradigm in consciousness research. We believe that this will improve the existing models of and analytical approaches to consciousness, allowing to better understand its neural mechanisms. It is also a necessary step to account for all aspects of conscious experience that people have during their everyday life.

AUTHOR CONTRIBUTIONS

MK drafted the initial version. All authors revised the manuscript. All authors contributed to the article and approved the submitted version.

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Tackling the Electro-Topography of the Selves Through the Sphere Model of Consciousness

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In the current hypothesis paper, we propose a novel examination of consciousness and self-awareness through the neuro-phenomenological theoretical model known as the Sphere Model of Consciousness (SMC). Our aim is to create a practical instrument to address several methodological issues in consciousness research. We present a preliminary attempt to validate the SMC *via* a simplified electrophysiological topographic map of the Self. This map depicts the gradual shift from faster to slower frequency bands that appears to mirror the dynamic between the various SMC states of Self. In order to explore our hypothesis that the SMC's different states of Self correspond to specific frequency bands, we present a mini-review of studies examining the electrophysiological activity that occurs within the different states of Self and in the context of specific meditation types. The theoretical argument presented here is that the SMC's hierarchical organization of three states of the Self mirrors the hierarchical organization of Focused Attention, Open Monitoring, and Non-Dual meditation types. This is followed by testable predictions and potential applications of the SMC and the hypotheses derived from it. To our knowledge, this is the first integrated electrophysiological account that combines types of Self and meditation practices. We suggest this electro-topographic framework of the Selves enables easier, clearer conceptualization of the connections between meditation types as well as increased understanding of wakefulness states and altered states of consciousness.

Keywords: consciousness, self, electrophysiology, meditation, executive functions, EEG, frequency

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INTRODUCTION

For centuries, scientists and philosophers have been tackling the question of what consciousness is, in order to understand what underlies human behavior, feeling, and action (Barrett and Satpute, 2013). Consciousness is a volatile phenomenon that is not easily defined, yet it determines our perception of what we consider as objective reality. While most operational definitions offer some attempt to characterize its various aspects, such definitions do not give a completely satisfying account of the way we know we are aware of our self and our existence (for a detailed argument, see Ardila, 2016). Consciousness is often regarded as consisting of two main components: awareness (the "content" of consciousness), and wakefulness or arousal (the "level" of consciousness). In addition to perception of the events of the "outside world," awareness also refers to the subjective experience of internal phenomena: our perception of inner "events," whether or not related to external ones, that comprises our subjective reality (Vithoulkas and Muresanu, 2014). This may also include self-awareness, i.e., awareness of one's internal world of thoughts, reflections, imagination, and emotions as an expression of the Self. There is also a more elaborate level of self-awareness involving higher-order cognitive mechanisms such as attentional focus on one's own mental states that is considered a distinct form of reflexive awareness (Peters, 2009), or "self as context" (Grieger, 1985).

Neuroscientific research has adopted different notions of the Self, the most frequently used of which is the binary distinction between the *Narrative Self* (NS) and the *Minimal Self* (MS) (James, 1890/1950; Gallagher, 2000; Legrand, 2006, 2007; Zahavi and Gallagher, 2008; Paoletti and Ben-Soussan, 2019, 2020; Gallagher and Zahavi, 2020; Paoletti et al., 2020). In the SMC, a third state is added, called *Overcoming of the Self,* indicating the complete absence of any sense of self (Paoletti, 2002a,b; Paoletti and Ben-Soussan, 2019, 2020; Paoletti et al., 2020). In the last decade, each of these three selves has been regarded in contemplative neuroscience as a particular configuration of self-awareness and mental contents (Gallagher, 2000; Jerath et al., 2015; Sugimura et al., 2021). There have also been attempts to link self-states to higher-order cognitive functions (i.e., executive functions), although the existing research is still scant (Ardila, 2016; Wade et al., 2018). Nonetheless, there is some evidence suggesting that the Self can be examined as a multidimensional construct denoted by: (1) First-person subjective reporting–such as the self-awareness experience; (2) Behavioral characteristics expressed through executive functions; and (3) Third-person objective measurements, such as electrophysiology (Fingelkurts et al., 2020). Accordingly, several theoretical models of selves have been proposed based on first-person phenomenology (James, 1890/1950; Gallagher, 2000; Legrand, 2006, 2007; Zahavi and Gallagher, 2008; Paoletti and Ben-Soussan, 2019, 2020; Fingelkurts et al., 2020; Gallagher and Zahavi, 2020; Paoletti et al., 2020); however, the challenge of empirically examining and validating them remains.

In this theoretical paper, we propose a novel examination of consciousness and self-awareness through the lens of the neuro-phenomenological theoretical model known as the Sphere Model of Consciousness (SMC; Paoletti, 2002a,b; Paoletti and Ben-Soussan, 2019, 2020; Paoletti et al., 2020). Although there are methodological challenges involved in examining and validating this model, we suggest ways to overcome these challenges through an "electro-topography of the Selves" that depicts cognitive and electrophysiological correlates of the different states of the Self, induced by different meditative practices. Of course, the subjective phenomenology of first-person experience remains an indispensable part of any consciousness research (Varela, 1996; Depraz et al., 2000). Thus, our aim is to create a practical instrument bridging first person reports and electrophysiology, in order to resolve some of the methodological challenges of consciousness research, as outlined below.

First, we will show how each state of the Self connects with a particular type of self-awareness and first-person phenomenology of experience, and then link these to executive functions. Second, by isolating some of the specific electrophysiological and neuronal correlates of each Self and meditative practice, we will suggest that hierarchies of meditation and the Selves (Laukkonen and Slagter, 2021) share a similar electro-topography. As the hierarchical electrophysiological correlates of Selves have yet to be conceptualized within one unified model, we will detail the electrophysiology of the Selves, followed by the electrophysiology of meditation and each specific Self, all within the framework of the Sphere Model of Consciousness (SMC) (**Figure 1A**; Paoletti, 2002a,b; Paoletti and Ben-Soussan, 2019, 2020; Paoletti et al., 2020).

THE SPHERE MODEL OF CONSCIOUSNESS, HIERARCHY OF SELVES, AND EXECUTIVE FUNCTIONS

The three Selves conceptualized in the SMC are: the Narrative Self, the Minimal Self, and the Overcoming of the Self (SMC; Paoletti, 2002a,b; Paoletti and Ben-Soussan, 2019, 2020; Paoletti et al., 2020; see **Figure 1A**). They are represented as concentric circles around a center (**Figure 1B**), with the Narrative Self (NS) on the periphery, the Minimal Self (MS) in the middle, and Overcoming of the Self (OCS) in the center.

Each Self is characterized by a particular state of self-awareness and first-person phenomenology that are expressed through features driven by functionality and cognition. In turn, the specific features of each state of the Self facilitate regulatory processes supported by executive functions (EFs) (Barkley, 2001; Nigg, 2017), as we will see shortly. The Narrative Self is considered as a self-image built through autobiographical memories and projections into the future; it involves awareness of personal identity and its continuity through time, as well as conceptual contents (Oatley, 2007). The Minimal Self emerges from the awareness of a situated living body as a sensorimotor unit that enables selfhood in the physical world in the "here and now" (James, 1890/1950; Gallagher, 2000), has a short temporal extension, and is endowed with a sense of action, property, and first person non-conceptual content. In our previous papers about the SMC, we specified the addition of a third state, called Overcoming of the Self (see **Figure 1B**), in which all sense of self disappears yet subjective experiences are still able to be experienced and eventually reported (Paoletti, 2002a,b; Paoletti and Ben-Soussan, 2019, 2020; Paoletti et al., 2020).

As we have said, each of the above-mentioned Selves is linked to core self-awareness features driven by functionality and cognition, and they facilitate regulatory processes supported by executive functions (EFs) (Barkley, 2001; Nigg, 2017). EFs are a set of higher-order cognitive functions often linked to the prefrontal cortex of the brain, consisting of three key components–working memory, inhibition, and cognitive flexibility–from which more complex and higher-order EFs are built (e.g., reasoning and planning) (Miyake et al., 2000; Diamond, 2013). EFs are essential for controlling unregulated behaviors, whether external (e.g., physical actions), as well as internal (e.g., meditative practices) (van Gaal et al., 2009;

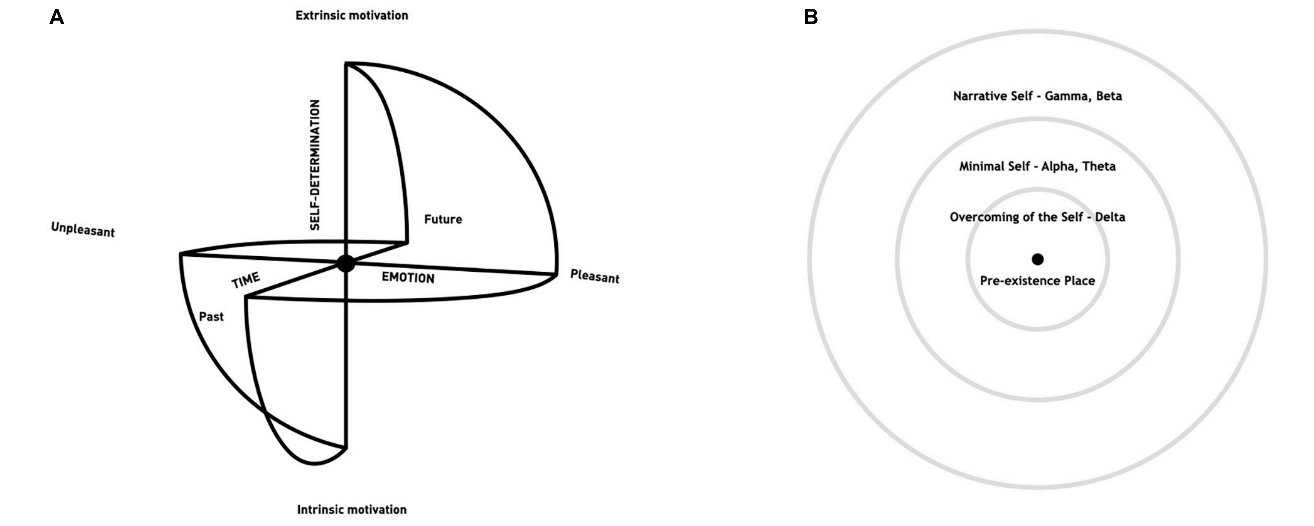

FIGURE 1 | (A) The Sphere Model of Consciousness. **(B)** Different Selves in the SMC and their main suggested electrophysiological correlate. The Narrative Self is related to Gamma and Beta, the Minimal Self is related to a shift toward Alpha and Theta (Carhart-Harris et al., 2014), and Overcoming the Self is mostly related to Delta activity (Dor-Ziderman et al., 2013; Paoletti et al., 2020). Adapted from Paoletti and Ben-Soussan (2019, 2020).

Hofmann et al., 2012). Furthermore, effective self-regulation processes require self-awareness of one's actions, thoughts, and feelings as well as the ability to make desired changes when needed (Heatherton, 2011). The multidimensional nature of EFs creates complexity regarding how they are conceptualized theoretically (Anderson, 2002; Welsh et al., 2006). This complexity is evident in the examination of latent components of EFs (e.g., shifting, inhibition) in relation to other multidimensional constructs, such as Self and awareness. The convergent and discriminant validity of these constructs is not clear, and the nature of their differences remains to be determined.

The different Selves–Narrative Self, Minimal Self, and Overcoming of the Self–may involve different usages of EFs. As we have seen above, the Narrative Self, depicted toward the periphery of the SMC sphere, is a more or less coherent self (or self-image) that is constituted of a past and a future in the various narratives that we and others tell about ourselves. It relies on declarative and episodic memories of the past or projection into the future (Vago and David, 2012) and, for an evaluative and personal perspective to be constituted and maintained over time, executive and volitional processes are necessary (Bortolan, 2020). Indeed, narrative abilities required to establish the Narrative Self are associated with core components of EFs and the higher-order cognitive functions that emerge from them, such as working-memory, inhibition, and set-shifting (Friend and Bates, 2014). However, once the Narrative Self is constructed and established, one can act more automatically with little forethought based on accumulated and internalized learning and experience. Thus, in the Narrative Self, a person can operate with relatively low self-awareness.

In contrast, the Minimal Self, depicted between the periphery and the center of the SMC sphere, is usually connected to conscious experience and a specific kind of self-awareness in which experiences are assimilated immediately as one's own experiences without need for any inferential processes (Lane, 2020). This form of self-experience in the Minimal Self is connected with pre-reflective self-consciousness (Bortolan, 2020). As Gallagher and Zahavi (2020) explain, on the one hand, self-experience is "non-observational" because it does not depend on any kind of introspective attitude taken by the subject toward the experience itself. On the other, it is "non-objectifying" because through it the self is not treated as an object, but rather as the subject of a conscious state. It can be claimed that in the Minimal Self state, a person deliberately reduces the use of executive processes and at the same time increases the level of bodily self-awareness.

Finally, as the level of consciousness of the Self approaches the center of the SMC sphere, toward the Overcoming of the Self, the necessity of EFs may decrease considerably, or even cease completely.[1] It is also entirely possible that the use of EFs

[1]In relation to this, in certain meditation practices, attention must eventually be released in favor of a form of bare or non-preferential attention, while in non-dual meditation practices, attention is released altogether (Dunne, 2011) as it claims to employ reflexive awareness that permits non-dual witnessing of the subject-object dichotomy and results in a pure (non-dual) awareness. In fact, according to some traditions, our inability to ordinarily detect non-dual awareness "is due to an obscuration of this reflexive property by mistaken cognitions arising from substrate consciousness. Although NDA [non-dual awareness] is experienced in meditation as a vivid presence of empty awareness that knows Itself directly without mediation by conceptual thought, substrate consciousness is experienced as a pleasantly restful absorbed state, akin to deep sleep yet not entirely unconscious" (Josipovic, 2014, pp. 2). In addition, the voluntary "letting go" in "states of flow," a transitory state between the MN and OCS, is related to altered states of consciousness (ASC). This deliberate reduction in the use of executive processes can also occur in the experience of flow (Csikszentmihalyi, 2000). Flow may result from a voluntary act occurring in both meditation and sports, a tuning in that involves "letting go" of goal (Jackson and Csikszentmihalyi, 1999; Lutz, 2009; Brown and Leary, 2016; Paoletti et al., 2020). It is important to note that alpha activity has been found to be related to the experience of flow (Katahira et al., 2018) and considering the involvement of alpha frequency both in flow and

in different Selves may not only vary in how *much* they are involved but also in the *way* they are involved. For example, a recent review (Gallant, 2016) highlighted a specific, instead of general, improvement in inhibition following mindfulness meditation, but showed inconsistent benefits in memory and cognitive flexibility, the other two main components of EFs (Miyake et al., 2000).

TOWARD AN ELECTRO-TOPOGRAPHY OF THE SELVES

In the last few years, there have been several attempts to link different features of self-awareness (e.g., identity, witnessing) with their electrophysiological correlates (Raffone et al., 2019; Fingelkurts et al., 2020; Sugimura et al., 2021), indicating a noticeable interest of neuroscientific research in finding a method to correlate first-person phenomenology and objective measures. One such attempt at a three-dimensional construct model for complex experiential selfhood was proposed, focusing on cortical alpha activity (Fingelkurts et al., 2020). It suggests that increased frontal alpha connectivity during the experience of a "*non-symbolic, non-linguistic sense of self-presenting being*," such as a sharper, more vivid experience of being a witnessing agent for oneself, possibly reflects being more conscious and able to access the external world, as well as the first-person perspective (Fingelkurts et al., 2020). Furthermore, temporal dynamics reflected in the brain's electrophysiological activity have been linked by Sugimura et al. (2021) to another core feature of self-awareness, namely, the sense of consistency of self. In turn, the subjective sense of an integrated and coherent Self across time, conceptualized as identity (Erikson, 1968), has been correlated to better cognitive performance, as well as to enhanced moral judgment and creative problem solving (Dietrich and Kanso, 2010; Travis et al., 2011; Charles et al., 2014).

Models of the self, such as those proposed by Fingelkurts et al. (2020) and Sugimura et al. (2021) focus mostly on alpha cortical sources. Yet, contemplative studies, which serve as excellent means of examining the states of Self, have also emphasized the importance of additional bands as well (Travis et al., 2010; Glicksohn and Berkovich-Ohana, 2011, 2012; Kerr et al., 2011; Muthukumaraswamy et al., 2013; Flor-Henry et al., 2017; Wahbeh et al., 2018; Glicksohn and Ben-Soussan, 2020). Taking this into consideration, we suggest the inclusion of additional frequency bands in order to find more comprehensive electrophysiological marker evidence differentiating the different Selves.

Toward this aim, we present a preliminary attempt to integrate into the SMC a simplified topographic map of the Selves by band, in which the NS is related to higher frequency bands, while the transition toward the center of the sphere that is associated with the MS is related to a shifting toward lower frequency bands (see **Figure 1B**; Dor-Ziderman et al., 2013; Carhart-Harris et al., 2014; Paoletti et al., 2020), ultimately leading toward the state of OCS (see **Figure 2**).

We also posit that the electro-topography of the Selves aligns with a hierarchy of meditation practices, from Focused Attention (FA) to Open Monitoring (OM) to Non-Dual (ND) meditation (Laukkonen and Slagter, 2021).[2] Meditation provides us an excellent tool for investigating the nature of the Self, especially in the rare states of consciousness in which self-processing changes (Laukkonen and Slagter, 2021). Understanding how meditation modulates neural oscillations[3] may help elucidate the relationship between these brain oscillations and cognitive processes, as well as the different states of Self they may induce. Accordingly, we will show how these three related meditation practices, namely, FA, OM, and ND, follow a similar pattern as the Selves of increasingly slower frequency bands[4] approaching the center of the SMC sphere.

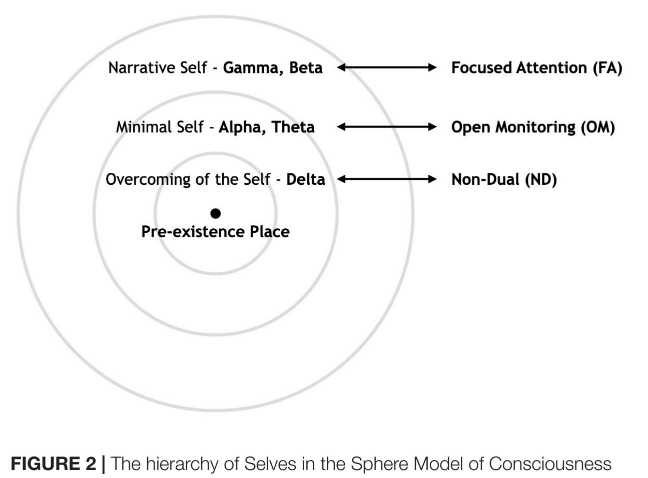

FIGURE 2 | The hierarchy of Selves in the Sphere Model of Consciousness corresponding to the hierarchy of meditation and their primary electrophysiological correlates.

as main difference between Altered States and Higher States, this voluntary "letting go" could be critical in discriminating between these states of consciousness.

[2] Another reason for the similarities between electrophysiological correlates of the electro-topography of the Selves and meditation types could be related to the different executive functions required for each of these states, which may be related to different levels of self-awareness, as we have seen in Section "The Sphere Model of Consciousness, Hierarchy of Selves, and Executive Functions."

[3] In particular, neural oscillations can be evaluated in a local region or between various regions of the brain. The strength of a particular oscillatory frequency in a particular region can be analyzed using a power analysis. Coherence, on the other hand, is the degree of coupling of a particular frequency between two different brain regions and can be used as an indicator of functional connectivity. EEG and MEG can both be used to investigate power and coherence within a particular frequency band.

[4] FA meditation requires voluntary focusing attention on a chosen object, OM meditation involves non-reactive monitoring of the content of experience from moment to moment (Lutz et al., 2009), and ND meditation aims for awareness that is unchanging regardless of what happens in experience (Josipovic, 2010; Dunne, 2011; Metzinger, 2020). ND awareness is characterized by its reflexive property—it knows itself to be conscious without relying on conceptual cognition (Josipovic, 2014; Laukkonen and Slagter, 2021). These meditation types also reflect different neural activity. FA, such as in the case of Tibetan Buddhist, Buddhist, and Chinese practices (Travis et al., 2010), has been mostly associated with gamma and beta activity (Hinterberger et al., 2014), OM with theta activity (Lee et al., 2018) and ND with delta activity (Knyazev, 2012; Berman and Stevens, 2015).

Thus, we will attempt to show that hierarchical organization based on the level of consciousness of the three types of the Self, which mirrors the hierarchical organization of meditation practice types, can be electrophysiologically measured through frequency bands. This electrophysiological topographic map of the self, reflecting a gradual shift from faster frequency bands, namely, Gamma (30–70 Hz) and Beta (13–30 Hz), to slower ones, namely, Alpha (8–12 Hz), Theta (4–8 Hz), and eventually Delta (1–4 Hz) as we get closer to the center of the Sphere. Thus, we propose three main hypotheses that can be examined through evidence-based electro-topography as specified below:

Hypothesis 1: The Narrative Self Primarily Involves Gamma and Beta

Empirical grounding for the first hypothesis is based on the finding that Gamma and Beta bands are often correlated with EFs such as focused attention and cognitive effort (Ward, 2003). Since Gamma and Beta are attributed both to FA and working memory, which is essential for the Narrative Self (Laukkonen and Slagter, 2021), we posit that the Narrative Self will be electrophysiologically related to FA meditation.

In fact, Gamma has been consistently reported to increase during engaging self-referential processing and focused attention in different cognitive tasks (Engel et al., 2001; Fell et al., 2003), both of which are related to the Narrative Self (Mantini et al., 2007; Chen et al., 2008), while a general decrease in this band has been reported during more relaxed states of meditation.

Beta is typically associated with sensorimotor processing (Symons et al., 2016). This is supported by studies that have shown a decrease in Beta during OM (Dor-Ziderman et al., 2013; Faber et al., 2015), Transcendental Meditation (Tomljenoviæ et al., 2016), and following an intensive 3-month meditation retreat (Slagter et al., 2007). Decreased Beta activity might be understood as decreased active processing consistent with the traditional understanding that Beta activity is associated with a more active and aroused brain-processing state (Slagter et al., 2009). The findings regarding this frequency band mirror those regarding Gamma frequencies: increasing in relation to the Narrative Self state and decreasing in more relaxed states. Thus, our hypothesis that the Narrative Self is related to FA meditation (Laukkonen and Slagter, 2021), is centered on the notion that both will elicit primarily Gamma and Beta frequencies.

Hypothesis 2: The Minimal Self Primarily Involves Alpha and Theta

Empirical grounding for the second hypothesis is centered around findings that Alpha and Theta frequencies have been found to increase in more relaxed states, lower arousal, in association with meditation, and with an internally directed focus of attention (Cooper et al., 2003; Takahashi et al., 2005; Lomas et al., 2015; Cona et al., 2020), all of which are related to the Minimal Self (see Section "The Sphere Model of Consciousness, Hierarchy of Selves, and Executive Functions" above). Many studies have found increased Alpha to be associated with meditation, such as Zen and Transcendental Meditation (Kasamatsu and Hirai, 1966; Wallace et al., 1971; Banquet, 1973; Murata et al., 1994, 2004; Yamamoto et al., 2006; see also Baerentsen et al., 2001 for a possible explanation of frontal cortical-subcortical system dominance in Zen meditation initiation).

There are different possible reasons for this relationship between Alpha frequency and meditation. DeLosAngeles et al. (2016) suggested that the widely reported increased Alpha power in meditation could be interpretable as a marker of practice or ease in task performance rather than specific to meditation. Beauregard et al. (2009) have instead suggested that higher frontal and temporal Alpha during meditation is an index of reduced cortical arousal associated with a relaxation response. In addition, as Kerr et al. (2013) beautifully described in their review, with somatic focus, mindfulness' top-down alpha rhythm modulation "*enhances gain control which, in turn, sensitizes practitioners to better detect and regulate when the mind wanders from its somatic focus*" (pp. 1), a feature fundamentally associated with the Minimal Self. In turn, enhanced regulation of somatic mind-wandering may be an important early stage of mindfulness training that leads to enhanced cognitive regulation and metacognition.

While both OM and FA are related to increased frontal Alpha amplitude and synchrony (Travis, 2001), a recent study reported that OM resulted in an increase in Alpha power, compared to FA, to meditation naïve controls (Himalayan Yoga), and to mind wandering (Braboszcz et al., 2017). There is also evidence that experienced meditators have increased prefrontal and parietal Alpha power during sleep (Dentico et al., 2016; regarding the sleep-wakefulness continuum, see also subsection The Sleep-Wakefulness Continuum below). One reason for this difference between OM and FA is that the top-down regulation of alpha is considered a key mechanism by which advanced OM practitioners learn to disengage attention in order to maintain greater attentional flexibility (Kerr et al., 2013). Alpha is not the only frequency that seems to be particularly related to OM; frontal and parietal Theta coherence have been found to increase in particular during this type of meditation (Cahn et al., 2013).

In addition, both Alpha and Theta are closely related to executive functions such as working memory (Sauseng et al., 2005a). Alpha frequency also plays a critical role in inhibition (Klimesch et al., 2007; Klimesch, 2011) and cognitive flexibility (Fink et al., 2009; Wolff et al., 2017), the other two main components of executive functions.

Theta is also associated with other relevant findings. Notably, Sugimura et al. (2021) reported that participants who tested well in having a strong sense of who they are (i.e., identity synthesis) exhibited increased Theta waves with low noise contamination in their frontal lobe, while those who reported feelings of a temporally changeable and fragmented self (i.e., identity confusion) displayed more Beta waves with high noise interference in the centroparietal lobe. In addition, frontocentral Alpha waves correlated negatively with identity confusion, and frontal Theta waves showed positive relationships with identity synthesis (Sugimura et al., 2021). Additionally, Aftanas and Golocheikine (2001) suggest that Theta is related to thoughtless awareness and bliss.

Taken together, these findings are particularly significant for linking the increase in Alpha and Theta bands to the phenomenology of the Minimal Self. A stronger sense of oneself is, in fact, reported during the Minimal Self state, which is characterized by bodily perception and a more consistent and continuous self-perception compared to the Narrative Self. Moreover, presuming that the Minimal Self is in alignment with OM meditation, both should elicit Alpha and Theta frequencies in particular.

Hypothesis 3: Overcoming of the Self Primarily Involves Delta Frequency

Empirical grounding for the third hypothesis centers on the finding that Delta is the main frequency associated with non-dual meditative states and higher states of consciousness (Berman and Stevens, 2015). In fact lower frequency bands, namely, Delta (for a recent review, see Wahbeh et al., 2018), are related to meditation's "core," and thus are depicted toward the center of the SMC sphere (Paoletti and Ben-Soussan, 2020). This leads us to the third hypothesis that Delta should be primarily associated with Overcoming of the Self (see Section "The Sphere Model of Consciousness, Hierarchy of Selves, and Executive Functions"), and that Non-Dual meditation, which we theorize corresponds with the OCS, should also be particularly associated with Delta.

Delta is reported to increase in deep meditation, especially with higher states of consciousness (Mason et al., 1997; Parker et al., 2013; Berman and Stevens, 2015; Parker, 2017). Unusual Delta activity generated in deep meditation is affiliated with non-conceptual awareness; it may enhance the capacity to suddenly recognize complex, subtle informational patterns that serve to provide novel, relevant solutions to complex problems through insight (Horan, 2009). Consistent with our current hypothesis and supported by previous meditation research Berman and Stevens (2015) found increased Delta, Theta, and Alpha activity during meditation (for a review, see Ivanovski and Malhi, 2007; Wahbeh et al., 2018).

In addition, combining hypothesis 1, 2, and 3 demonstrating a gradual slowing of the frequencies as we approach the center of the SMC sphere, we can also observe a differentiation between general meditation and non-dual states (in which the participant transcends the separation between self and other). The opposite trend was observed for Gamma activity, which was higher during the meditation sessions compared to non-dual states (Berman and Stevens, 2015). Similarly, Berkovich-Ohana et al. (2012), who examined participants who possessed one of three levels of mindfulness expertise versus non-experienced controls, found that mindfulness practitioners generally exhibited reduced resting-state frontal low Gamma power as compared to controls. They also found decreased resting-state Gamma functional connectivity—representing Default Monde Network (DMN) deactivation—among the long-term practitioners, suggesting a trait or long-lasting effect of reduced mind-wandering and self-related processing that is generally associated with the Narrative Self (Berkovich-Ohana et al., 2012, 2013). In addition, creativity, as measured by ideational fluency and flexibility, which was higher among the long-term practitioners than the short-term practitioners and control participants, was negatively correlated with Gamma interhemispheric functional connectivity (Berkovich-Ohana et al., 2017). Thus, one should keep in mind that different meditation techniques can produce different electrophysiological results, depending, among other things, on the extent of experience of the practitioner, and the experimental design (Berman and Stevens, 2015).

In sum, recent electrophysiological studies of meditation consistently demonstrate increased slower frequency bands, and either decreased DMN activation or measures of enhanced sensory, and attentional processing with concomitantly decreased automated reactivity (for a review, see Britton et al., 2014) which could be integrated in the SMC and the hierarchy of Selves. See **Table 1** for our mini-review linking different meditation practices and the phenomenological description of the Selves to the electrophysiological findings. The literature review presented in **Table 1** was conducted in order to examine our hypothesis that there is a hierarchical order of the electrophysiological correlates that corresponds with the hierarchical order of the three types of the selves and related meditation practices.

DISCUSSION ON THE MODEL AND CURRENT HYPOTHESIS

Of the articles reviewed, 83% support our model of the electro-topography of the Selves with increasingly slower frequency bands as one approaches the center of the SMC sphere (**Table 2**).

To further support our hypothesis, we will now also present a number of our previous study results regarding the relationship between frequency bands and self-awareness through: (1) Mindfulness meditation, (2) Quadrato Motor Training (QMT), and (3) The Whole-Body Perceptual Deprivation chamber (OVO-WBPD) (**Table 3**). The last two are techniques that were created from the SMC itself. The results support the relationship between electrophysiological frequency bands and the SMC. More specifically:

1. Mindfulness meditation. We previously reported higher fluency and flexibility, which are measures of creativity, among two long-term mindfulness practitioners as compared to short-term mindfulness practitioners and control participants, which were negatively correlated with trait default-mode gamma inter-hemispheric functional connectivity (Berkovich-Ohana et al., 2017). This study indicates that a form of mindfulness meditation that shares similarities with QMT can reduce the role of the DMN and the involvement of gamma frequency band. In terms of the model, mindfulness meditation can promote distancing from Narrative Self and from fast frequency bands like gamma. This is in line with the proposed electro-topography, since processes and networks (DMN) commonly related to the Narrative Self have also been found associated with gamma frequency outside the context of the SMC and the scope of

TABLE 1 | Synthesis table summing our mini-review linking different meditation practices and the phenomenological description of the Selves to the electrophysiological findings.

	Meditation	Self		Results
Gamma	OM	NS	+	Berkovich-Ohana et al., 2012
	Multiple	NS	+	Berman and Stevens, 2015
	Multiple	NS	+	Hinterberger et al., 2014
	Multiple	NS	+	Lehmann et al., 2001
	Review	NS	+	Lomas et al., 2015
	Neurofeedback	NS	\	Van Lutterveld et al., 2017
	OM/FA*	MS	+	Cahn et al., 2010
	FA	MS	-	DeLosAngeles et al., 2016
	LKM	MS	+	Lutz et al., 2004
	ND	OTS	+	Flor-Henry et al., 2017
	ND	OTS	+	Huels et al., 2021
	FA	OTS	-	Travis et al., 2010
Beta	Multiple	NS/MS	+	Dunn et al., 1999
	FA	MS	-	DeLosAngeles et al., 2016
	OM	MS	-	Faber et al., 2015
	FA	MS	-	Travis et al., 2010
	ND	OTS	+	Flor-Henry et al., 2017
	Multiple	OTS	-	Hinterberger et al., 2014
	Multiple	OTS	\	Lehmann et al., 2012

	Meditation	Self		Results
Alpha	Multiple	NS	\	Marzetti et al., 2014
	FA	NS	\	Rodriguez-Larios and Alaerts, 2021
	FA	MS	+	Aftanas and Golosheykin, 2005
	FA	MS	+	Banquet, 1973
	FA	MS	+	DeLosAngeles et al., 2016
	Multiple	MS	+	Dunn et al., 1999
	OM	MS	+	Faber et al., 2015
	Review	MS	+	Fell et al., 2010
	OM	MS	+	Kasamatsu and Hirai, 1966
	OM	MS	\	Kerr et al., 2013
	Review	MS	+	Lomas et al., 2015
	OM	MS	+	Murata et al., 1994
	OM	MS	+	Murata et al., 2004
	OM	MS	\	Rodriguez-Larios et al., 2020
	OM	MS	+	Takahashi et al., 2005
	Review	MS	+	Wahbeh et al., 2018
	FA	MS	+	Wallace et al., 1971
	FA	MS	+	Yamamoto et al., 2006
	Multiple	OTS	+	Berman and Stevens, 2015
	ND	OTS	+	Flor-Henry et al., 2017
	Multiple	OTS	-	Hinterberger et al., 2014
	OM	OTS	-	Lo et al., 2003
	FA	OTS	+	Travis et al., 2010
	OM	OTS	-	Winter et al., 2020

	Meditation	Self		Results
Theta	OM/FA*	NS	+	Lutz et al., 2009
	FA	NS	\	Rodriguez-Larios and Alaerts, 2021
	FA	MS	+	Aftanas and Golosheykin, 2005
	FA	MS	\	Baijal and Srinivasan, 2010
	OM/FA*	MS	+	Cahn et al., 2010
	FA	MS	+	DeLosAngeles et al., 2016
	Multiple	MS	+	Dunn et al., 1999
	Review	MS	+	Fell et al., 2010
	OM	MS	+	Kubota et al., 2001
	Review	MS	+	Lomas et al., 2015
	OM	MS	+	Murata et al., 1994
	OM	MS	\	Rodriguez-Larios et al., 2020
	OM	MS	+	Takahashi et al., 2005
	Multiple	OTS	+	Berman and Stevens, 2015
	ND	OTS	+	Flor-Henry et al., 2017
	Multiple	OTS	-	Hinterberger et al., 2014
	OM	OTS	+	Winter et al., 2020
Delta	OM/FA*	MS	-	Cahn et al., 2010
	Multiple	MS	+	Dunn et al., 1999
	OM	MS	+	Faber et al., 2008
	Multiple	MS	\	Lehmann et al., 2012
	FA	MS	\	Tei et al., 2009
	Multiple	OTS	+	Berman and Stevens, 2015
	ND	OTS	+	Flor-Henry et al., 2017
	Multiple	OTS	-	Hinterberger et al., 2014
	ND	OTS	+	Parker, 2017
	ND	OTS	+	Parker et al., 2013

*Attribution of self has been done accordingly to the phenomenological description of results done by authors of cited papers. Main hypotheses are colored in blue scale (with increasingly dark blue color as the findings relate toward the center of the sphere). Highlighted cells are findings related to the main hypotheses of the proposed model. Increase: +; Decrease: -; Changes in connectivity or Neurofeedback: *Vipassana meditation (VM) can be understood as a combination of FA meditation and OM meditation (Lutz et al., 2008).*

the present paper (e.g., Engel et al., 2001; Laufs et al., 2003a,b; Chen et al., 2008; Berkovich-Ohana et al., 2012).

2. The QMT is a specifically structured movement meditation in which the participants make a step into one of 12 possible directions according to verbal instruction (Paoletti and Salvagio, 2011; Dotan Ben-Soussan et al., 2013). QMT relates mainly to processes associated with the Minimal Self as it requires ongoing second-by-second mindful awareness to the body and to the upcoming command (Ben-Soussan et al., 2019b; Leshem et al., 2020).
3. The OVO-WBPD chamber is an altered sensory environment in the form of a human-sized egg (uovo in Italian literally

TABLE 2 | Numerical summary of literature mini-review findings.

	Agreement with hypotheses	
Papers	***N***	**% of agreement with main hypotheses**
Papers regarding main hypotheses	24	83%
Papers in agreement with main hypotheses	20	

Number and percentage of studies in agreement with our hypotheses. Reviews were not counted, and papers in agreement with hypotheses for more than one frequency were only counted once. Papers were considered "relevant to main hypotheses" if they examined the hypothesized frequency in association with a phenomenological description fitting the hypothesized-as-correlated Self state. The direction of the findings was then evaluated to see if it agreed with the hypotheses.

TABLE 3 | Summary of studies relating Quadrato Motor Training (QMT), OVO Whole Body Perceptual Deprivation chamber (OVO-WBPD), and mindfulness meditation to different states of Self and their electrophysiological correlates.

Towards the center of the Sphere Model of Consciousness

Study	Self Involved	Technique	General Results	Neural Correlates
Berkovich-Ohana et al., 2017	NS	Mindfulness Meditation	Enhanced creativity by long-term mindfulness training	Negatively correlation of creativity results with gamma inter-hemispheric functional connectivity
Lasaponara et al., 2016	NS/MS	QMT	EEG changes related to activation in higher order processing and mental effort Sharpened specialization during eyes closed and eyes open brain states, refining their specific electrophysiological characteristics	Enhancement of the shift from posterior to frontal Beta/Gamma from eyes closed to eyes open resting state after QMT Peculiar EEG bands characterizing eyes closed (alpha synchronization) and eyes open (Beta activity) resting state were positively modulated and increased after QMT.
Ben-Soussan et al., 2011	MS	QMT	Changes in time production correlated with frontal theta power and coherence changes	Bilateral temporal theta coherence during the time production task increased following QMT
Ben Soussan et al., 2013	MS	QMT	Change in ideational flexibility was correlated with change in alpha coherence	Increased inter- and intra-hemispheric alpha coherence
Ben-Soussan et al., 2014a	MS	QMT	Improved performance on a speeded reading task (both Control and Dyslexic)	Increased cerebellar oscillatory alpha power (Dyslexic) Increased inter-hemispheric alpha coherence (Dyslexic more than Controls)
Ben-Soussan et al., 2014b	MS	QMT	Decreased mind-wandering and narrative focused thought Increased reflectivity in both genders	Decreased gamma coherence in males compared to females Increased alpha and theta coherence in females while the opposite was found for males
Lasaponara et al., 2017	MS	QMT	Significant changes in functional connectivity in the alpha band following QMT	Limbic and fronto-temporal alpha connectivity increased during resting state following QMT
De Fano et al., 2019	MS	QMT	Increased frontal theta in last two blocks of QMT compared to the first one	Increased prefrontal and frontocentral theta
Glicksohn et al., 2019	MS/OTS	OVO-WBDP	Subjective experience and gender related differences in alpha profiles of participants	R>L asymmetry for males and L>R asymmetry for females Positive (frontal L<R alpha) or Negative (frontal L>R alpha) affect More verbal (L>R alpha) or a more imagistic (R>L alpha) thinking More trancelike (frontal>parietal alpha) or more reflective (frontal<parietal alpha) state of consciousness
Ben-Soussan et al. 2019	OTS	OVO-WBDP	Achievement of a state of absorption	Increased delta and beta1 in left inferior frontal cortex and in the insula

Main hypotheses are colored in blue scale (with increasingly dark blue color as the findings relate toward the center of the sphere).

means "egg"). Based on the SMC, the OVO-WBPD was specifically built with the aim of facilitating an immersive experience and an increased state of presence (Paoletti, 2002a). While the QMT is related more to the Minimal Self, the experience in the OVO-WBPD is more related to the Overcoming of the Self, since it induces a state of absorption and dissolves spatial boundaries (Ben-Soussan et al., 2019a).

Taken together, these techniques and their electrophysiological correlates (shown in **Table 3**) suggest a gradual shift from the Narrative Self and higher frequency bands toward the Minimal Self and then toward Overcoming of the Self and lower frequency bands that we are proposing with the present mini-review.

In **Table 4**, we also highlight the spatial localization of the EEG results reported in this mini-review. It is possible to see that Alpha and Theta frequency bands display the most consistent results with predominant frontal activity, while Gamma and Delta frequency bands are less spatially localized. One possible explanation for these results could be the scale-dependent mechanism highlighted by Von Stein and Sarnthein (2000) for visual processing. The authors proposed that the more local the synchronization, the higher the frequency involved. In particular, they showed that "local interactions during visual processing involve gamma frequency dynamics, semantical interactions between temporal and parietal cortex involve beta frequency dynamics, and very long-range interactions [. . .] a low theta or alpha frequency range."

Although these conclusion concern visual processing, they appear highly relevant because they are consistent with the findings reported in **Table 4** and they offer a cogent explanation as to why the Delta frequency band is more globally distributed than other "faster" frequencies. In addition, Von Stein and Sarnthein (2000) stated that Alpha and Theta frequencies seem to be "specifically involved in processing of internal mental context" which is in line with the role that these frequency

TABLE 4 | Summary of main studies and their localization.

	Meditation	Self	Results		Area localization
Gamma	OM	**NS**	+	Berkovich-Ohana et al., 2012	Parieto-Occipital
	Multiple	**NS**	+	Berman and Stevens, 2015	Frontal, Central, Parietal, Temporal, and Occipital
	Multiple	**NS**	+	Hinterberger et al., 2014	Central and Parietal
	Multiple	**NS**	+	Lehmann et al., 2001	Frontal and Temporo-Parietal
	Neurofeedback	**NS**	\	Van Lutterveld et al., 2017	PCC
	OM/FA	**MS**	+	Cahn et al., 2010	Parieto-Occipital
	FA	**MS**	-	DeLosAngeles et al., 2016	Central
	LKM	**MS**	+	Lutz et al., 2004	Frontal and Temporo-Parietal
	ND	**OTS**	+	Flor-Henry et al., 2017	Parietal
	ND	**OTS**	+	Huels et al., 2021	N/A
	FA	**OTS**	-	Travis et al., 2010	Frontal and Temporal
Beta	Multiple	**NS/MS**	+	Dunn et al., 1999	Central and Parietal
	FA	**MS**	-	DeLosAngeles et al., 2016	Central
	OM	**MS**	-	Faber et al., 2015	Central and Parietal
	FA	**MS**	-	Travis et al., 2010	Frontal and Parietal
	ND	**OTS**	+	Flor-Henry et al., 2017	Frontal
	Multiple	**OTS**	-	Hinterberger et al., 2014	Parietal
	Multiple	**OTS**	\	Lehmann et al., 2012	Central
Alpha	Multiple	**NS**	\	Marzetti et al., 2014	PCC
	FA	**NS**	\	Rodriguez-Larios and Alaerts, 2021	N/A
	FA	**MS**	+	Aftanas and Golosheykin, 2005	Frontal
	FA	**MS**	+	Banquet, 1973	Frontal
	FA	**MS**	+	DeLosAngeles et al., 2016	Frontal and Temporo-Parietal
	Multiple	**MS**	+	Dunn et al., 1999	Central and Parietal
	OM	**MS**	+	Faber et al., 2015	Frontal and Temporal
	OM	**MS**	+	Kasamatsu and Hirai, 1966	Frontal
	OM	**MS**	\	Kerr et al., 2013	Central
	OM	**MS**	+	Murata et al., 1994	Frontal
	OM	**MS**	+	Murata et al., 2004	Frontal
	OM	**MS**	\	Rodriguez-Larios et al., 2020	N/A
	OM	**MS**	+	Takahashi et al., 2005	Frontal
	FA	**MS**	+	Wallace et al., 1971	Frontal
	FA	**MS**	+	Yamamoto et al., 2006	Frontal
	Multiple	**OTS**	+	Berman and Stevens, 2015	Frontal, Central, Parietal, Temporal, and Occipital
	ND	**OTS**	+	Flor-Henry et al., 2017	Frontal, Temporal, Parietal and Occipital
	Multiple	**OTS**	+	Hinterberger et al., 2014	Parietal
	OM	**OTS**	-	Lo et al., 2003	N/A
	FA	**OTS**	+	Travis et al., 2010	Frontal and Central
	OM	**OTS**	-	Winter et al., 2020	Parietal
Theta	OM/FA	**NS**	+	Lutz et al., 2009	Frontal
	FA	**NS**	\	Rodriguez-Larios and Alaerts, 2021	N/A
	FA	**MS**	+	Aftanas and Golosheykin, 2005	Frontal
	FA	**MS**	\	Baijal and Srinivasan, 2010	Frontal Increase, Parietal Decrease
	OM/FA	**MS**	+	Cahn et al., 2010	Frontal
	FA	**MS**	+	DeLosAngeles et al., 2016	Frontal and Temporo-Parietal
	Multiple	**MS**	+	Dunn et al., 1999	Frontal, Central, Parietal, Temporal, and Occipital
	OM	**MS**	+	Kubota et al., 2001	Frontal
	OM	**MS**	+	Murata et al., 1994	Frontal
	OM	**MS**	\	Rodriguez-Larios et al., 2020	N/A
	OM	**MS**	+	Takahashi et al., 2005	Frontal
	Multiple	**OTS**	+	Berman and Stevens, 2015	Frontal, Central, Parietal, Temporal, and Occipital
	ND	**OTS**	+	Flor-Henry et al., 2017	Frontal and Temporo-Parietal
	Multiple	**OTS**	-	Hinterberger et al., 2014	Frontal, Central, Parietal, Temporal, and Occipital
	OM	**OTS**	+	Winter et al., 2020	Frontal, Central, Parietal, and Occipital

(Continued)

TABLE 4 | (Continued)

	Meditation	Self	Results		Area localization
Delta	OM/FA	**MS**	-	Cahn et al., 2010	Frontal
	Multiple	**MS**	+	Dunn et al., 1999	Frontal and Parietal
	OM	**MS**	+	Faber et al., 2008	PFC
	Multiple	**MS**	\	Lehmann et al., 2012	Frontal and Parietal
	FA	**MS**	\	Tei et al., 2009	Frontal Increase; Central, Parietal, and Temporal Decrease
	Multiple	**OTS**	+	Berman and Stevens, 2015	Frontal, Central, Parietal, Temporal, and Occipital
	ND	**OTS**	+	Flor-Henry et al., 2017	Temporal
	Multiple	**OTS**	-	Hinterberger et al., 2014	Frontal, Central, Parietal, Temporal, and Occipital
	ND	**OTS**	+	Parker, 2017	N/A
	ND	**OTS**	+	Parker et al., 2013	N/A

Reviews were excluded from this table. Not applicable (N/A) are studies without a clear or not reported localization of results. Main hypotheses are colored in blue scale (with increasingly dark blue color as the findings relate toward the center of the sphere).

bands have in the proposed electro-topography model and in the previous literature (Takahashi et al., 2005; Jensen and Mazaheri, 2010; Klimesch, 2012; Benedek, 2018; Cona et al., 2020), further supporting our hypothesis.

Suggested Hypothesis Testing and Application

First-Person Phenomenology and Self-Awareness

Probably the biggest challenge in the study of consciousness is how to deal with the first-person subjective experience within an objective measurable framework. According to the SMC, all phenomenal characteristics of experience can be placed along three axes: Time, Emotion, and Self-Determination (see **Figure 1**; Paoletti, 2002a; Paoletti and Ben-Soussan, 2019, 2020, 2021). The highest degree of self-awareness can be represented as an equal relationship between the periphery of the sphere, or the extremes of the axes on which the features of first-person experience are placed, and the center, where we place consciousness-as-such/non-dual consciousness. While the spherical matrix of the model provides a diagram for representing first-person experience, our hypotheses on the electro-topography of the Selves might enable us in future studies to find neurophysiological correlates for first-person experience. For instance, recalling Raffone et al. (2019) argument about the Beta frequency (the possibility of different levels or grades of self-awareness within each dimension of Self), we might observe this frequency in a state of self-projection as well in FA meditation with good self-awareness.

Our model may also serve as a guideline to refine the research on correlates to self-awareness phenomenology: when Beta is present, for example, we hypothesize a connection with the Narrative Self, but can we also detect differences in its coherence, amplitude, and localization in specific brain areas? What would that imply? For example, can we detect electrophysiological brain correlates in areas suggested in different models as the main areas for consciousness correlation–like Broadman Area 10 (Raffone and Srinivasan, 2009) or the precuneus (Josipovic, 2019)–according to the Self we are observing?

Since several works have already been published on the topic, we will only focus briefly on the problem of ineffability (see Section "The Problem of Ineffability"), and then present several difficulties that have not (with few exceptions) been sufficiently addressed yet in the research literature, such as the sleep-wakefulness continuum (see also Section "The Sleep-Wakefulness Continuum") and the distinction between higher and altered states of consciousness (see Section "The Importance of Differentiating Between Altered and Higher States of Consciousness"). As detailed above (Section "The Sphere Model of Consciousness, Hierarchy of Selves, and Executive Functions"), the Minimal Self and the Narrative Self appear to be more directly related to executive functions (EFs), while the Overcoming of the Self presents us with the problem of ineffability, which will now be shortly addressed.

The Problem of Ineffability

In order to electrophysiologically and behaviorally map the different Selves, we need to distinguish between consciousness and its contents and, consequently, deal with the challenge of ineffability. One of the main obstacles in studying and quantifying higher states of consciousness is the ineffability of subjective experiences. When one's sense of self "disappears," as is reported in first-person accounts of the Overcoming of the Self, we encounter something hardly measurable by the same behavioral and cognitive parameters used to assess other states of the Self which are mostly identified with/described by the processes involved (e.g., Narrative Self is associated with autobiographical processes and conceptual contents; Gallagher, 2000; Oatley, 2007). Yet, taking neurophenomenological studies for reference, we can electrophysiologically measure whether consciousness-without-content or non-dual awareness is in line with some of the correlates for that state, as suggested by the most recent models of consciousness proposed by Raffone and Srinivasan (2009); Metzinger (2018), and Josipovic (2019). These models conceptualize consciousness-without-content, non-dual awareness, and the Overcoming of the Self (in the case of the SMC) which can be easily measured using EEG. Indeed, various attempts are being made to do so (Berkovich-Ohana et al., 2017). For this reason, the hypothesized electrophysiological model could provide an interesting index (i.e., increase in Delta frequency band) to identify the state in which any sense of self disappears and reportable cognitive processes and behavioral measures become less informative.

The Sleep-Wakefulness Continuum

Another possible application for the proposed electro-topographic model is in the examination and differentiation of various states of wakefulness. More specifically, the sleep-wakefulness continuum is often treated as dichotomous, but various cultures have described different states of awareness outside this dichotomy (Walsh and Vaughan, 1993). One of these states is the outcome of transcendent meditation: a deeply restful state but with fully alert inner wakefulness (Alexander and Sands, 1993). Utilizing this state of consciousness as an example of an "in-between state" along the sleep-wakefulness continuum, we will apply our proposed model to explore if the proposed electro-topography matches the electroencephalography findings in the literature.

Further, considering the phenomenological description of transcendental consciousness as a profound state of relaxation but with preserved awareness, and following the SMC-based hypotheses presented in this paper, we postulate that this state of consciousness will be found associated with increased activity in Alpha and Theta bands (Wallace et al., 1971; Banquet, 1973; Mason et al., 1997; Yamamoto et al., 2006).

For example, Theta plays important role in memory encoding and consolidation during sleep (for a review, see Rasch and Born, 2007). Nonetheless, as Kirov et al. (2009) demonstrated, application of transcranial slow oscillation stimulation (tSOS) can enhance the process of memory consolidation not only during sleep (Marshall et al., 2006), but also in wakeful states. This enhancement was accompanied by a widespread increase of Theta activity (Kirov et al., 2009). Thus, the hypothesized correlation between the Theta frequency and the Minimal Self could help in understanding differences in states of awareness along the sleep-wakefulness continuum, and to further expanding its currently dichotomous definition into more subtle distinctions between different wakefulness states.

The Importance of Differentiating Between Altered and Higher States of Consciousness

So far, we have demonstrated how the hypothesized model is in alignment with different meditation traditions. In addition, we further suggested that the current hypothesized electro-topography could be useful in guiding new contemplative neuroscience investigations into differentiating Altered States (AS) from Higher States (HS) of consciousness. Altered States (AS) are traditionally defined as "*a qualitative alteration in the overall pattern of mental functioning, such that the experiencer feels consciousness radically differently from the 'normal' way it functions. It should be noted that an AS is not defined by a particular content of consciousness, behavior, or physiologic change, but in terms of overall patterning.*" (Tart, 1972; for a review on neurobiological basis of AS, see also Vaitl et al., 2005).

However, not all AS are alike. While higher states of consciousness are accompanied by improved executive functionality, the opposite is true for many cases of drug-induced AS. Moreover, electrophysiologically, HS are accompanied by slower frequency bands and are considered more integrated states (Mason et al., 1997), while EEG and MRI studies of drug-induced AS report an opposite trend that could be regarded as fragmentation and consequent deregulation.

Moreover, an important distinction must be made between general AS and HS. According to Tart (1972), higher states, in particular, can be associated with superior cognitive functioning or can be more profound than other states; these states can include insights into oneself, insights into others, intuitive understanding of the nature of the universe, or comprehension of an individual's place in the overall scheme of things (in relation to insight, see also Section The Sphere Model of Consciousness and Self Are Dynamic below). Although this description is phenomenologically exhaustive, it is not sufficient (as acknowledged by the author) to distinguish "*any unequivocally higher state*" Electrophysiology, therefore, could be a reliable method to reach a more precise discrimination between HS and AS.

Electrophysiological studies and the proposed model can, indeed, help in differentiating between AS and HS of consciousness. Although this is not the aim of the paper, we will focus briefly on the differentiation between contemplative-induced HS of consciousness versus drug-induced AS, in order to provide a preliminary framework. To examine our hypothesis, we reviewed the literature from the perspective of its applicability to SMC electro-topography. We found that the main difference between AS and HS is primarily in Alpha and

TABLE 5 | Summary of examined studies regarding Alpha Frequency in Altered States (AS) and Higher States (HS) differentiation.

	Study	State achievement	Alpha
Altered States of Consciousness	Fink, 1969	LSD Intake	+
	Sannita et al., 1987	Scopolamine Intake	–
	Sloan et al., 1992	Scopolamine Intake	–
	Neufeld et al., 1994	Scopolamine Intake	–
	Ebert et al., 2001	Scopolamine Intake	–
	Riba et al., 2002	Ayahuasca Intake	–
	Osipova et al., 2003	Scopolamine Intake	–
	Riba et al., 2004	Ayahuasca Intake	–
	Muthukumaraswamy et al., 2013	Psilocybin Intake	–
	Kometer et al., 2015	Psilocybin Intake	–
	Carhart-Harris et al., 2016	LSD Intake	–
Higher States of Consciousness	Travis et al., 2002	Trascendent Meditation	+
	Abdullah and Omar, 2011	Religious Contemplation	+
	Doufesh et al., 2012	Religious Contemplation	+
	Doufesh et al., 2014	Religious Contemplation	+
	Vaghefi et al., 2015	Religious Contemplation	+
	Berman and Stevens, 2015	Multiple types of Meditation	+
	DeLosAngeles et al., 2016	Concentrative Meditation	+
	Al-Galal and Alshaikhli, 2017	Religious Contemplation	+
	Wahbeh et al., 2018	Trascendent Meditation	+
	Barcelona et al., 2020	Religious Contemplation	+

higher frequencies: HS are consistently related to increased Alpha activity while AS displays reduced Alpha activity in this EEG band (see **Table 5**). Taken together, in HS, deep states of meditation and attention are achieved through discipline and focus which largely involve EF training. While achievement of an AS is easier, often being driven by consumed substances, there is a lesser degree of control over the whole experience. This lesser degree of intentional and skillful navigation of the experiences could undermine the replicability and increase possible dangers related to drug-induced AS compared to the safety and replicability of HS. A good example for this, would be a professional athlete or dancer that can intentionally and reliably perform difficult and potentially dangerous movements compared to a novice that perform the same actions by chance, risking injuries and without being able to replicate or even know how that happened. This example is also quite fitting to the findings of Fink et al. (2009), who found increased Alpha activity in professional dancers compared to novices during mental creation of dances.

To sum up, HS could be linked to increased Alpha activity because these states entail effort and inhibition in controlling the process, while AS could be related to disinhibition and loss of control as reflected by overall decreased Alpha activity. This could be explained by the proposed electro-topography model as the result of increased internally directed attention and embodiment (Minimal Self) during the process of achieving HS, which is lacking during a drug-induced AS.

LIMITATIONS AND CONSIDERATIONS IN THE INTERPRETATION OF THE MODEL

Despite the supporting evidence, there are limitations to the proposed model that should be acknowledged. First, the electrotopographic model may seem oversimplified because, as depicted, the examined frequency bands often underlie a wide range of different cognitive functions. However, we are not suggesting that a given meditation type, for instance, is exclusively associated with one frequency band's activity, but rather we hypothesize that a specific meditation type relies more on that frequency than others. Of necessity, the graphic depiction of this requires some simplification.

In addition, there are two patterns of results that apparently contradict to our hypothesis. First, regarding our hypothesis that the Minimal Self primarily involves Alpha and Theta frequencies, paradoxically, some findings in the literature have reported increased Alpha and Theta activity during mind-wandering (Rodriguez-Larios et al., 2020; Rodriguez-Larios and Alaerts, 2021), which is related to the Narrative Self. However, this could also be attributed to retrieval and manipulation of memory information (Bastiaansen et al., 2002; Jensen et al., 2002; Sauseng et al., 2002, 2004, 2005a,b; Moran et al., 2010; see also Staresina and Wimber, 2019 for a review). Second, increased Gamma/decreased Delta during deep meditation could be related to the central role that Gamma plays in brain mechanisms underlying information processing (Lehmann et al., 2001). Increased Gamma activity could also be related to the spiritual/religious/mystic aspects of the meditative state (Beauregard et al., 2009) and therefore to higher states of consciousness with fullness of content, while lower frequency bands (Delta, Theta, and Alpha) could be related to states of thoughtless emptiness (meaning higher yet content-less states). Perhaps further discrimination between "deeper" states, taking into consideration not only the level of consciousness involved but also the content of those states, would be worthwhile to explore in future research.

A further aspect to consider in future research is the strong relationship among phenomenological experiences, EFs, and electrophysiology that have been reported across many studies exploring the concept of Self. Future studies should explore these relationships in a systematic way, taking into consideration different styles of meditation (see Gallant, 2016 for a review examining EFs with regard to mindfulness meditation).

What is more, as mentioned in the Introduction, the subjective dimension of self-awareness remains inescapable. For instance, based on Raffone et al. (2019) review, we can argument about the possibility of different levels or grades of self-awareness within each dimension of Self, namely, we might observe Beta frequency in a state of self-projection as well in FA meditation with good self-awareness.

The Sphere Model of Consciousness and Self Are Dynamic

The proposed model is dynamic in several noteworthy ways. As the Self is dynamic, so might one oscillate between meditative states during meditation practice. For example, movement between FA and OM often occurs (Laukkonen and Slagter, 2021). In the same way, mechanisms and functions underlying the Self could also be dynamic: an active and intentional effort could dynamically restructure self-awareness, consciousness, and EFs in different ways. Indeed, two of the most studied phenomena that share some form of self-awareness and restructuring with meditation are cognitive reappraisal[5] and insight.[6]

Many studies identify an association between Gamma and the process of achieving deeper states of meditation, as well as with the degree of visual imagery involved in these states. In particular,

[5]Reappraisal refers to the act of changing the way one thinks about emotional events (for a review, see John and Gross, 2004). In particular, cognitive reappraisal strategies have been investigated mainly in relation to aversive stimuli (Ochsner et al., 2004; Banks et al., 2007; Kanske et al., 2011; Schulze et al., 2011). This cognitive strategy for emotional regulation has been found to be strongly related to contemplative practices. Garland et al. (2009, 2010, 2011) and Garland and Howard (2013) theorized that mindfulness training can facilitate cognitive reappraisal. Moreover, Hanley et al. (2014) demonstrated that a substantial proportion of practitioners who use a wide range of contemplative practices reportedly engaged in mindful reappraisal techniques as a means of coping with serious stressors or the hassles of everyday life.

[6]Insight is a sudden comprehension, the famous "*Eureka!*" that can result in a new interpretation, a reorganization or restructuring of the elements of a situation and can point to the solution to a problem (Sternberg and Davidson, 1995). This definition seems to be very similar to the following description of a sudden transformation occurring during meditation: "*A common experience for long term meditators is that the 'new' knowledge being encoded is, paradoxically, the experience of a thought-free state transforming all phenomena into novelty. Phenomena become new because "there is no succession of perception of this knowledge; it takes in all things simultaneously, at a glance*" (Nikhilananda, 1956, pp. 203; from Horan, 2009).

the Gamma band could be associated with the hyper-focused attention required to *achieve* non-dual states, but not with the non-dual state itself (Berman and Stevens, 2015). This could be due to the relationship between Gamma, and meditation, cognitive reappraisal, and insight[7] (Jung-Beeman et al., 2004): These processes rely on a restructuring of awareness producing similar effects (e.g., sudden and clear solutions; new perception of emotional stimuli). However, these could also be reached through different mechanisms: active and intentional efforts to solve a problem rely, at least partly, on executive functions (Sandkühler and Bhattacharya, 2008; Schmeichel et al., 2008). Meditation, in contrast, may rely on deeper and more self-less states that involve less conceptual processing.

From an electrophysiological point of view, as discussed earlier, different investigations have found decreased prefrontal Alpha activity during reappraisal (Parvaz et al., 2012; Choi et al., 2016; Li et al., 2021) in association with increased prefrontal Theta activity (Ertl et al., 2013). Possible generators of frontal Theta oscillations have been suggested to reside in the medial prefrontal cortex (PFC)/anterior cingulate complex (ACC) (Pizzagalli et al., 2002; Mulert et al., 2007a,b). However, although the ACC is notably one of the areas most associated with insight (Dietrich and Kanso, 2010), it is thought to prompt weak, subconscious solutions (Kounios and Beeman, 2009).

What could be the reason for these similarities in brain activity? One reason for shared areas and electrophysiological correlates is that both cognitive reappraisal and insight have been associated with core EFs, such as working memory processes (Schmeichel et al., 2008). For example, frontal Theta activity in the ACC has been found to increase with task difficulty and memory demands (Gevins et al., 1997; Lazarev, 1998; Kahana et al., 1999; Wilson et al., 1999; Krause et al., 2000; but see Bastiaansen et al., 2002). Successful retrieval is also associated with activity in the Theta band (Weiss and Rappelsberger, 2000; Klimesch et al., 2001; Sederberg et al., 2003). Thus, such similarities could result from the involvement of wider, more global functions that underlie all the Self states.

CONCLUSION

In conclusion, to our knowledge, this is the first attempt to systematically integrate electrophysiological accounts with different Selves and meditation practices. Our core proposal is that there is an electro-topographic hierarchy of the Selves that mirrors the hierarchy of meditation types. We have shown a parallel between FA/OM/ND and NS/MS/OCS in which Gamma and Beta = the Narrative Self and Focused Attention meditation; Alpha and Theta = the Minimal Self and Open Monitoring meditation; and Delta = Overcoming of the Self and Non-Dual meditation. Our evidence should be viewed as preliminary since these are complex processes that involve many different areas, networks, and frequency bands all at once. Future studies should examine the parallel between the electrophysiological change and the neurophenomenological shift between Selves, employing different training paradigms that utilize whole brain analysis of different frequency bands.

Moreover, we also highlighted how the frequency bands involved in both hierarchies are associated with EFs. Future behavioral and electrophysiological studies should aim to assess how EFs in general, and their components in specific, could play a critical role in structuring the Self and in the switching between different states (for a very recent review on mapping EFs and their components using electrical subcortical stimulation, see Landers et al., 2021).

Additionally, given the aforementioned role of neuronal noise in "identity confusion" (Sugimura et al., 2021) and the lack of it in feelings of identity consistency and integration, future studies should also explore possible parallels between phenomenological and electrophysiological silence, which is a very common feature in meditative practices (for empirical and theoretical contributions to neural, psychological, and contemplative correlates of silence, see Ben-Soussan et al., 2021).

Although a comprehensive electrophysiological model encompassing all frequency bands and their dynamics—including detailed temporal and spatial localization evidence—is still far from being achieved, there are relevant findings in recent literature that offer potential direction for future studies. For example, a recent work of Rodriguez-Larios et al. (2020) examined the Alpha-Theta cross-frequency coupling and considered these two frequency bands and their dynamics during meditation. This is particularly interesting because authors not only examined Alpha and Theta bands from the point of view of a linear increased/decreased activity, but also how reciprocal changes in these frequencies' activity (especially their ratio) could facilitate meditation training. Such dynamics were also explored in the field of neurofeedback, in which the importance of the Alpha/Theta ratio in relation to creativity and artistic performance was emphasized (Gruzelier, 2009; Gruzelier et al., 2014a,b). These findings may offer directions for expanding and refining our proposed electro-topography. Moreover, these directions should orient and guide the field of consciousness studies and contemplative neuroscience, which should systematically start reporting all the different frequency bands and to integrate evidence concerning electroencephalographic dynamics into the various models that currently exist.

In summary, based on the presented evidence, we suggest that the Narrative Self may be related to reduced self-awareness in the "here and now" compared to the Minimal Self that is more mindful. Further, shifting between the Narrative Self to the Minimal Self correlates with an increase in self-awareness which, in turn, correlates with slower frequency bands, namely, Alpha and Theta oscillation (Paoletti and Ben-Soussan, 2020). The third state of Overcoming of the Self correlates with increasingly slower frequency bands, namely, Delta. Similarly, different kinds of meditations align with the same electrophysiological hierarchy. However, this does not necessarily imply that one meditation is better than another in enhancing self-awareness, only that there is a gradual shift in self-awareness' phenomenology (Laukkonen and Slagter, 2021).

[7]This could also explain the difference in Gamma between experienced and novice meditators (i.e., less Gamma = less effort among experienced meditators in achieving a non-dual state). For example, long-term Vipassana meditation contributes to increased occipital Gamma power and is related to long-term meditational expertise and enhanced sensory awareness (Cahn et al., 2010).

Our proposed model may aid in resolving some inconsistencies between different frequency bands and locations pointed to in previous studies as the main correlates of consciousness and meditative practices. According to our proposal, these different frequency bands and locations may result from the different attentional states and related Selves that were examined. The model can be tested and applied in different contexts such as in the examination of advanced meditative states, higher states versus altered states, and levels of wakefulness. Accordingly, this new electro-topographic framework of the Self and meditation may more easily facilitate greater understanding of the connections between them, with implications for research in wakefulness states, altered states of consciousness, and executive functions.

AUTHOR CONTRIBUTIONS

PP was the creator of the Sphere Model of Consciousness and contributed parts related to the neuro-psychological applications of his model. TB-S mostly contributed to the electro-topographic map of the self. RL mostly contributed parts related to the executive functions. MP conducted the mini-review. All authors contributed to the article hypothesis, writing, and approved the submitted version.

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