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BIASED COGNITIONS AND SOCIAL ANXIETY: BUILDING A GLOBAL FRAMEWORK FOR INTEGRATING COGNITIVE, BEHAVIORAL, AND NEURAL PROCESSES

Topic Editors

Alexandre Heeren, Wolf-Gero Lange, Pierre Philippot and Quincy J. J. Wong

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BIASED COGNITIONS AND SOCIAL ANXIETY: BUILDING A GLOBAL FRAMEWORK FOR INTEGRATING COGNITIVE, BEHAVIORAL AND NEURAL PROCESSES

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Social anxiety (SA) is a common and incapacitating disorder that has been associated with seriously impaired career, academic, and general social functioning. Regarding epidemiological data, SA has a lifetime prevalence of 12.1% and is the fourth most common psychopathological disorder (Kessler et al., 2005).

At a fundamental point of view, the most prominent cognitive models of SA posit that biased cognitions contribute to the development and maintenance of the disorder (e.g., Clark & Wells, 1995; Rapee & Heimberg, 1997). Over the last decades, a large body of research has provided evidence that individuals suffering from SA exhibit such biased cognitions at the level of visual attention, memory of social encounters, interpretation of social events, and in judgment of social cues. Such biased cognitions in SA has been studied in different ways within cognitive psychology, behavioral psychology, clinical psychology, and cognitive neuroscience over the last few decades, yet, integrative approaches for channeling all information into a unified account of biased cognitions in SA has not been presented so far.

The present Research Topic aims to bring together theses different ways, and to highlight findings and methods which can unify research across these areas. In particular, this Research Topic aims to advance the current theoretical models of SA and set the stage for future developments of the field by clarifying and linking theoretical concepts across disciplines.

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EDITORIAL
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Biased cognitions and social anxiety: building a global framework for integrating cognitive, behavioral, and neural processes

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Social anxiety is a common emotional experience that occurs in response to the perceived threat of evaluation from others before, during, or after social situations. When social anxiety reaches a high level of severity such that functioning is impaired and associated with considerable distress, we refer to it as Social Anxiety Disorder (SAD). With a lifetime prevalence ranging from 7.3 to 12.1%, SAD is the fourth most common psychiatric disorder (Kessler et al., 2005). SAD has an early onset and tends to follow a chronic and debilitating course if untreated (e.g., Hayward et al., 2008). SAD usually precedes other anxiety, mood, and substance abuse disorders (e.g., Randall et al., 2001; Lampe et al., 2003).

Although the personal and economic costs of SAD as well as its comorbidity with other disorders have been very well-documented, uncertainty remains regarding the etiological and maintenance factors underlying this condition. As highlighted by Hirsch and Clark (2004), a curious feature of this condition is that it persists even if most individuals with SAD in their daily life perform naturalistic exposure to at least some feared social situations on a regular basis. At a fundamental level, one possible explanation for the enduring nature of SAD may be the way socially anxious individuals process social information. Accordingly, cognitive theorists have argued that negatively biased information-processing may contribute to the maintenance of SAD (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997; Hirsch and Clark, 2004; Morrison and Heimberg, 2013). An information-processing bias reflects a general processing advantage for disorder-relevant information in a given cognitive domain (e.g., attention, memory, interpretation, mental imagery). Such biases would lead individuals with SAD to evaluate social situations as more threatening than they actually are, and in turn, contribute to the maintenance of the disorder (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997).

Since the development of maintenance models for SAD (e.g., Clark and Wells, 1995), cumulative evidence indicates that SAD individuals do indeed exhibit such biased cognitions (for a review, see Hirsch and Clark, 2004), and further research has begun to uncover the behavioral, cognitive, and neural correlates of these biases (e.g., Rossignol et al., 2012; Hattingh et al., 2013). Given this progress, researchers have recently started to probe the causal nature of such biased information-processing by directly manipulating these biases in the context of etiological and maintenance frameworks for SAD. Recent findings suggest that these biases do indeed play a crucial role in the development (e.g., Hirsch et al., 2006; Heeren et al., 2012) and the maintenance (e.g., Amir et al., 2009; Clerkin and Teachman, 2010; Amir and Taylor, 2012) of SAD.

The research advances to date have generated interest in the biases of SAD within the scientific and practitioners community. However, integrative advances for channeling all information into a unified account of the different cognitive biases operating in SAD have not been offered thus far. For this purpose, the present Research Topic brings together a number of opinions, perspectives, reviews, and original research that provides state-of-the-art updates on this thriving relation between biased cognitions and SAD. These contributions provide a much needed advance in the current conceptualization of the mechanisms underlying biased cognitions in SAD and set the stage for future research avenues by clarifying and bridging conceptual gaps between different areas. The 11 papers of this Research Topic reveal that the diversity of the methods and approaches used can tell us more than the study of either topic in seclusion. Several key themes can be identified.

First, Haller et al. (2014) have provided a comprehensive neurodevelopmental framework to understand the brain and cognitive mechanisms that lead to biased cognitions in SAD.

Second, two research papers have focused on the implication of working memory capacity that may underlie biased cognition in SAD: Moriya and Sugiura (2013) investigated the role of working memory capacity in the inhibition of goal-irrelevant information and the direction of attention to distractors, while Salemink et al. (2013) explored the moderating nature of working memory capacity on threat-related interpretative bias.

Third, two papers have shed light on the need to move beyond face- and word-stimuli in the assessment and conceptualization of cognitive biases. Indeed, most of the available evidence comes from research paradigms using faces or words as materials. Social information, however, is also conveyed through other channels, such as vocal and postural cues. In their paper, Gilboa-Schechtman and Shachar-Lavie (2013) reviewed the fundamental and applied additive value of integrating nonverbal social cues in SAD research. Compatibly, Peschard et al. (2014) proposed a cross-modal perspective to advance the understanding of cognitive biases in SAD.

Fourth, three papers have focused on the development of new research approaches to gauge the key features of SAD. Van der Molen et al. (2014) explored the neural foundations of anticipating and processing social-evaluative feedback using event-related potentials. Gilboa-Schechtman et al. (2014) examined both self-reported and acoustic (i.e., vibrations of the vocal folds during phonation and speech) reactions to exclusion, acceptance, and popularity induced by a participation in an online ball-tossing game in SAD. In a critical review, Schulze et al. (2013) questioned whether gaze perception is a suitable way to assess attentional biases in SAD.

Finally, three papers have highlighted the need to translate basic advances in cognitive biases repeatedly observed among SAD patients into new innovative neurocognitive interventions directly targeting these biases. Maoz et al. (2013) reported an attempt to develop a subliminal computerized attention bias modification training program. Rinck et al. (2013) reported the benefits of a computerized training program that directly modifies the avoidance tendencies away from smiling faces exhibited by SAD individuals. Finally, Pictet (2014) commented on the acute gain of promoting positive mental imagery in cognitive bias modification when treating SAD individuals.

In sum, this Research Topic illustrates without question how different scientific approaches lead to an important road map for researchers and practitioners in the field of cognitive biases in SAD. We hope that this Topic moves the field closer toward a global framework for understanding the cognitive biases in SAD.

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REFERENCES

Amir, N., Beard, C., Taylor, C. T., Klumpp, H., Elias, J., Burns, M., et al. (2009). Attention training in individuals with generalized social phobia: a randomized controlled trial. *J. Consult. Clin. Psychol.* 77, 961–973. doi: 10.1037/a0016685

Amir, N., and Taylor, C. T. (2012). Interpretation training in individuals with generalized social anxiety disorder: a randomized controlled trial. *J. Consult. Clin. Psychol.* 80, 497–511. doi: 10.1037/a0026928

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Social Phobia: Diagnosis, Assessment, and Treatment,* eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope, and F. R., Schneier (New York, NY: Guilford Press), 69–93.

Clerkin, E. M., and Teachman, B. A. (2010). Training implicit social anxiety associations: an experimental intervention. *J. Anxiety Disord.* 24, 300–308. doi: 10.1016/j.janxdis.2010.01.001

Gilboa-Schechtman, E., Galili, L., Sahar, Y., and Amir, O. (2014). Being "in" or "out" of the game: subjective and acoustic reactions to exclusion and popularity in social anxiety. *Front. Hum. Neurosci.* 8:147. doi: 10.3389/fnhum.2014.00147

Gilboa-Schechtman, E., and Shachar-Lavie, I. (2013). More than a face: a unified theoretical perspective on nonverbal social cue processing in social anxiety. *Front. Hum. Neurosci.* 7:904. doi: 10.3389/fnhum.2013.00904

Haller, S. P. W., Cohen Kadosh, K., and Lau, J. Y. F. (2014). A developmental angle to understanding the mechanisms of biased cognitions in social anxiety. *Front. Hum. Neurosci.* 7:846. doi: 10.3389/fnhum.2013.00846

Hattingh, C. J., Ipser, J., Tromp, S. A., Syal, S., Lochner, C., Brools, S. J., et al. (2013). Functional magnetic resonance imaging during emotion recognition in social anxiety disorder: an activation likelihood meta-analysis. *Front. Hum. Neurosci.* 6:347. doi: 10.3389/fnhum.2012.00347

Hayward, C., Wilson, K. A., Lagle, K., Kraemer, H. C., Killen, J. D., and Taylor, C. B. (2008). The developmental psychopathology of social anxiety in adolescents. *Depress. Anxiety* 25, 200–206. doi: 10.1002/da.20289

Heeren, A., Peschard, V., and Philippot, P. (2012). The causal role of attentional bias for threat cues in social anxiety: a test on a cyber-ostracism task. *Cogn. Ther. Res.* 36, 512–521. doi: 10.1007/s10608-011-9394-7

Hirsch, C. R., and Clark, D. M. (2004). Information-processing bias in social phobia. *Clin. Psychol. Rev.* 24, 799–825. doi: 10.1016/j.cpr.2004.07.005

Hirsch, C. R., Mathews, A., Clark, D. M., Williams, R., and Morrison, J. A. (2006). The causal role of negative imagery in social anxiety: a test in confident public speakers. *J. Behav. Ther. Exp. Psychiatry* 37, 159–170. doi: 10.1016/j.jbtep.2005.03.003

Kessler, R. C., Chiu, W., Demler, O., and Walters, E., (2005). Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. *Arch. Gen. Psychiatry* 62, 617–627. doi: 10.1001/archpsyc.62.6.617

Lampe, L., Slade, T., Issakidis, C., and Andrews, G. (2003). Social phobia in the Australian National Survey of Mental Health and Well-Being (NSMHWB). *Psychol. Med.* 33, 637–646. doi: 10.1017/S0033291703007621

Maoz, K., Abend, R., Fox, N. A., Pine, D. S., and Bar-Haim, Y. (2013). Subliminal attention bias modification training in socially anxious individuals. *Front. Hum. Neurosci.* 7:389. doi: 10.3389/fnhum.2013.00389

Moriya, J., and Sugiura, Y. (2013). Socially anxious individuals with low working memory capacity could not inhibit the goal-irrelevant information. *Front. Hum. Neurosci.* 7:840. doi: 10.3389/fnhum.2013.00840

Morrison, A. S., and Heimberg, R. G. (2013). Social anxiety and social anxiety disorder. *Annu. Rev. Clin. Psychol.* 9, 249–274. doi: 10.1146/annurev-clinpsy-050212-185631

Peschard, V., Maurage, P., and Philippot, P. (2014). Towards a cross-modal perspective of emotional perception in social anxiety: review and future directions. *Front. Hum. Neurosci.* 8:322. doi: 10.3389/fnhum.2014.00322

Pictet, A. (2014). Looking on the bright side in social anxiety: the potential benefit of promoting positive mental imagery. *Front. Hum. Neurosci.* 8:43. doi: 10.3389/fnhum.2014.00043

Randall, C. L., Thomas, S., and Thevos, A. K. (2001). Concurrent alcoholism and social anxiety disorder: a first step toward developing effective treatments. *Alcohol. Clin. Exp. Res.* 25, 210–220. doi: 10.1111/j.1530-0277.2001.tb02201.x

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/S0005-7967(97)00022-3

Rinck, M., Telli, S., Kampmann, I. L., Woud, M. L., Kerstholt, M., Te Velthuis, S., et al. (2013). Training approach-avoidance of smiling faces affects emotional vulnerability in socially anxious individuals. *Front. Hum. Neurosci.* 7:481. doi: 10.3389/fnhum.2013.00481

Rossignol, M., Campanella, S., Maurage, P., Heeren, A., Falbo, L., and Philippot, P. (2012). Enhanced perceptual responses during visual processing of facial stimuli in young socially anxious individuals. *Neurosci. Lett.* 526, 68–73. doi: 10.1016/j.neulet.2012.07.045

Salemink, E., Friese, M., Drake, E., Mackintosh, B., and Hoppitt, L. (2013). Indicators of implicit and explicit social anxiety influence threat-related interpretive bias as a function of working memory capacity. *Front. Hum. Neurosci.* 7:220. doi: 10.3389/fnhum.2013.00220

Schulze, L., Renneberg, B., and Lobmaier, J. S. (2013). Gaze perception in social anxiety and social anxiety disorder. *Front. Hum. Neurosci.* 7:872. doi: 10.3389/fnhum.2013.00872

Van der Molen, M. J. W., Poppelaars, E. S., Van Hartingsveldt, C. T. A., Harrewijn, A., Gunther Moor, B., and Westenberg, P. M. (2014). Fear of negative evaluation modulates electrocortical and behavioral responses when anticipating social evaluative feedback. *Front. Hum. Neurosci.* 7:936. doi: 10.3389/fnhum.2013.00936

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A developmental angle to understanding the mechanisms of biased cognitions in social anxiety

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INTRODUCTION

Social anxiety disorder (SAD) is debilitating and common, affecting 7.3–12.1% of the population (e.g., Wittchen et al., 1999; Kessler et al., 2005). Age-of-onset data show that SAD symptoms are often first experienced in late childhood or adolescence (Kessler et al., 2005). While adolescence is a period when many typical social fears and worries emerge, major questions remain as to why some youths are more vulnerable to experiencing persistent and impairing social anxiety. A key gap in current theoretical models of SAD etiology is an understanding of the mechanisms by which risk factors are expressed during development. In this opinion paper, we address this gap by first discussing the nature of age-typical increases in social fears and worries in the transition to adolescence and outlining possible brain-based developmental mechanisms by which these arise. Next, we discuss how these age-typical changes in neurocognitive functioning might, in a subset of adolescents, enable maladaptive processing biases in relation to social cues to emerge or be exacerbated. These processing biases may, in turn, contribute to the onset of persistent social anxiety.

ADOLESCENCE: A PERIOD OF AGE-TYPICAL INCREASES IN SOCIAL FEARS AND WORRIES

Adolescence is a transitional period demarcated by the onset of puberty, and ending with the assumption of a stable adult role (Lerner and Steinberg, 2004). This transitional period involves substantial physiological and psychological changes, currently understood to be orchestrated by a combination of experience-dependent and biologically programmed regulation of gene expression (Nelson et al., 2005; Gajados et al., 2010). Central to adolescent developments are hormonal changes associated with puberty. These likely initiate a cascade of morphological and neural maturations, which significantly impact on cognition and information processing (Sisk and Foster, 2004; Blakemore et al., 2010; Goddings et al., 2013). Of particular interest in the context of this opinion paper are the effects of these maturational changes on the processing of affective and social stimuli. In the last decade, there has been a surge in investigations of typical changes in the functioning of limbic and prefrontal networks across development, especially during social-affective processing (e.g., Pfeifer and Blakemore, 2012). Cross-sectional comparisons of functional neuroimaging data from multiple child/adolescent/adult age groups may lend insight into how typical developmental changes in the brain can give rise to adolescent-typical behaviors of heightened "emotionality" and "sociality". In turn, these may explain age-associated changes in social fears and worries in adolescence.

What typical neurodevelopmental changes might increase "emotionality" (that is, increased avoidance of threats and approach of rewards) across age? There is now a convincing corpus of data available documenting changes in the sensitivity of subcortical regions involved in basic processing of threat and reward such as the amygdalae and striatum. These data broadly suggest a peak in the neural response to monetary rewards, emotional faces and peer feedback in early to mid-adolescence, before decreasing toward adulthood (e.g., Monk et al., 2003; Ernst et al., 2005; Galvan et al., 2006; Hare et al., 2008; Van Leijenhorst et al., 2010; Pfeifer et al., 2011; Somerville et al., 2011; Chein et al., 2012; Gee et al., 2013). More protracted changes have also been noted in regulatory regions involved in modulating arousal. The few cross-sectional functional magnetic resonance imaging (fMRI) studies of adolescents have consistently found differences in medial and lateral functional subdivisions of the prefrontal cortex (PFC) in response to emotionally provocative stimuli between adolescents and adults (e.g., Yurgelun-Todd and Killgore, 2006; Masten et al., 2009; Gunther Moor et al., 2010, 2012; Lau et al., 2011; Pitskel et al., 2011; McRae et al., 2012). However, the directionality of these developmental differences is not always consistent, possibly because of variations associated with the social-motivational context of the task (see Crone and Dahl, 2012 for in-depth discussion). Nonetheless, additional recruitment of medial and lateral PFC regions in older age groups (relative to younger participants) has been tentatively interpreted as reflecting an increased ability to recruit these regions to effectively down-regulate subcortical arousal with age (e.g., Gunther Moor et al., 2010; Casey et al., 2011). Further support for this interpretation comes from studies showing that regulatory functional connectivity between PFC and subcortical regions continues to mature throughout adolescence (Hare et al., 2008; Pitskel et al., 2011; Gee et al., 2013). Synthesis of these data suggests that protracted maturation of prefrontal engagement together with a heightened reactivity of limbic regions to threatening and rewarding stimuli may be responsible for increased emotional responses in adolescence. Notably, these studies of age-associated functional differences occur against a backdrop of structural developments in these regions too, with data pointing to localized linear and non-linear restructuring as well as further integration within networks (e.g., Giedd et al., 1999; Paus et al., 1999; Sowell et al., 1999; Gogtay et al., 2004; Dennis et al., 2013).

What typical neurodevelopmental changes might increase "sociality" (that is, increased motivational salience of peers and understanding of complex social situations) across age? Continuous development throughout adolescence has been documented in the network involved in the understanding of others' behavior in terms of motivations, thoughts and feeling states ("mentalizing") (Blakemore, 2008; Mills et al., 2014). Developmental studies of mentalizing have consistently found a (relative) decrease in anterior/dorsal medial PFC activity and increase in posterior-temporal areas (such as the temporo-parietal junction and superior temporal sulcus) in response to tasks requiring mental state attribution when comparing early/mid adolescent to adult groups (Wang et al., 2006; Blakemore et al., 2007; Burnett et al., 2009; Guroglu et al., 2011). More recent studies have employed multiple adolescent age groups and have confirmed a continuous shift in functional contributions from frontal to temporal areas across adolescence whilst engaged in thinking about mental states (Gunther Moor et al., 2011; Van den Bos et al., 2011)—findings that have been suggested to reflect increased automaticity of engaging in mentalizing across adolescence (e.g., Blakemore, 2008; Van den Bos et al., 2011). Presumably such neurocognitive changes prepare the adolescent for navigation in a novel and possibly more complex social world.

In summary, changes in brain networks engaged by social-affective stimuli across adolescence may result in greater affective responding and a greater engagement with, and understanding of, complex interpersonal situations. These age-typical changes may, on the one hand, allow for more flexible responses enabling the adolescent to adapt rapidly to changing social contextual demands (Crone and Dahl, 2012). Yet, on the other hand, these normative brain developments, which change the perception of and importance placed on the social world, may increase social fears and worries. This may be particularly crucial given that some social environments are changing. For example, school transitions often mean longer time in school and greater workload, as well as more time spent interacting with peers socially and academically. Such changes may increase the opportunities for new academic pressures to emerge, and new peer groups and hierarchies to be formed.

ADOLESCENCE: A PERIOD OF PRECIPITATING INDIVIDUAL DIFFERENCES IN SOCIAL ANXIETY

While we suggest that most adolescents will experience age-associated increases in social fears and worries, in a minority of adolescents, more distressing forms of social anxiety may also emerge and persist. A key question is what makes these individuals different? Similar to adult models of SAD, theoretical considerations of child and adolescent SAD have emphasized biases in information processing (Clark and Wells, 1995; Rapee and Heimberg, 1997; Ollendick and Hirshfeld-Becker, 2002; Jarcho et al., 2013). *Attention* biases, that is, systematic differences in orienting to threat cues, have been documented in socially anxious children and adolescents (Stirling et al., 2006; Roy et al., 2008) and even in at-risk infants (offspring of socially anxious mothers) as young as 10 weeks (Creswell et al., 2008). Biases in the *interpretation* of ambiguous social information have also been found in socially anxious youths (Haller et al. A novel picture-based tool for measuring interpretation biases in adolescents, manuscript in preparation; Miers et al., 2008) although, interestingly, linkages between biased interpretations and symptoms are less consistently found in younger children (Waters et al., 2008; In-Albon et al., 2009; Creswell et al., 2013). It may either be that current measurement tools are not suitable for detecting interpretation biases in younger populations or that interpretation biases do not mature as risk factors until later in adolescence. Finally, biases in *expectations* of the outcomes of social-evaluative situations also characterize socially anxious individuals and at-risk populations (Cartwright-Hatton et al., 2003, 2005; Pass et al., 2012).

Recent fMRI studies have suggested that in adults, SAD-linked cognitive biases may be associated with individual differences in brain activity. Thus, biases in attention and the tendency to perceive ambiguous social cues such as neutral facial expressions as negative have been linked to impaired regulatory recruitment of fronto-amygdalae circuits and increased emotion-related neural responses of limbic areas in SAD individuals (e.g., Cooney et al., 2006; Blair et al., 2008). The few studies investigating the neural substrates of information processing and cognitions in adolescents with social concerns mostly find similar results (Killgore and Jurgelun-Todd, 2005; Pérez-Edgar et al., 2007; Guyer et al., 2008, 2014).

How might age-normative neural changes in social-affective regions impact on the expression of individual differences in cognitive biases thereby increasing vulnerability to SAD in adolescence? We suggest that age-typical changes in emotionality and sociality in adolescence may magnify differences across individuals such that those who already fall at the end of the continuous distribution shift further toward the extreme end. Speculatively, this can occur through two routes. First, developmental changes in the sensitivity of the "emotional brain" may further amplify attention and expectancy biases for potential threat cues. Bi-directional interactions between pre-existing cognitive biases and the plasticity of the adolescent brain may serve to amplify negative effects over time. Pre-existing cognitive biases will affect functional restructuring by biasing incoming information to further sensitize socio-affective networks. Hence, individuals with a pre-existing tendency to attend to negative aspects of social cues or situations—or to expect negative outcomes from these—may experience these to a greater degree and, to alleviate distress, may engage in maladaptive behavioral strategies such as avoidance. This will set up a vicious cycle, which, over time, reinforces these pre-existing maladaptive biases.

Secondly, developmental changes in the "social brain" may act as a vehicle for the expression of biases at the level of interpretation. As increased mentalizing abilities (being able to generate more "mental explanations" for others' behavior) emerge. The emergence of increased mentalizing abilities across adolescence may result in an increase in perceived complexity and ambiguity of daily social situations. Specifically, as these maturational brain developments are paralleled by increases in time spent with peers, this change in perception of social interactions may "bring out" in some individuals the tendency to interpret socially ambiguous cues in a more negative manner. This could also explain findings of why interpretation biases are not consistently found in younger populations—it may be that such biases in interpretation only become evident once these socio-cognitive capacities are attained.

In order to empirically investigate these hypotheses, studies need to assess whether certain neurocognitive factors characterize individuals with social anxiety at particular ages or at particular pubertal developmental stages. This can be done by looking at SAD-linked processing biases in individuals with high and low social anxiety (or with and without SAD) across different developmental age groups. Our prediction is that while attention, expectancy and interpretation biases at the behavioral and neural level characterize all participants with high levels of social anxiety (or who meet criteria for SAD), these group differences will prove to be far stronger in adolescents than in children. Moreover, we would predict that these age-by-group interactions are mediated by changes in "emotionality" and "sociality". Such hypotheses await future empirical investigations.

CONCLUSION

This opinion paper has highlighted how neuro-scientific insights on the level of normative functional changes during adolescence can generate novel hypotheses about the mechanisms underlying the emergence or exacerbation of individual differences related to social anxiety. We have described ways in which normative neurodevelopmental progressions could magnify pre-existing cognitive biases in attention, interpretation and expectations that are characteristic of persistent and impairing social fears and worries. We further provided directions as to how these hypotheses should be empirically investigated. Adolescence as a time of increased plasticity may also be an optimal time for administering neurocognitive interventions (e.g., Cohen Kadosh et al., 2013; Lau, 2013) as the exposure to specific adaptive or corrective experiences may result in long-term effects on neural architecture. Understanding the mechanisms by which normative neurodevelopmental changes may drive the expression of risk factors linked to social anxiety can extent current theoretical models of SAD and, in parallel, inform when early interventions should be effectively applied.

REFERENCES

Blair, K., Geraci, M., Devido, J., McCaffrey, D., Chen, G., Vythilingam, M., et al. (2008). Neutral response to self- and other referential praise and criticism in generalized social phobia. *Arch. Gen. Psychiatry* 65, 1176–1184. doi: 10.1001/archpsyc.65.10.1176

Blakemore, S.-J. (2008). The social brain in adolescence. *Nat. Rev. Neurosci.* 9, 267–277. doi: 10.1038/nrn2353

Blakemore, S. J., Burnett, S., and Dahl, R. E. (2010). The role of puberty in the developing adolescent brain. *Hum. Brain Mapp.* 31, 926–933. doi: 10.1002/hbm.21052

Blakemore, S.-J., den Ouden, H., Choudhury, S., and Frith, C. (2007). Adolescent development of the neural circuitry for thinking about intentions. *Soc. Cogn. Affect. Neurosci.* 2, 130–139. doi: 10.1093/scan/nsm009

Burnett, S., Bird, G., Moll, J., Frith, C., and Blakemore, S.-J. (2009). Development during adolescence of the neural processing of social emotion. *J. Cogn. Neurosci.* 21, 1736–1750. doi: 10.1162/jocn.2009.21121

Cartwright-Hatton, S., Hodges, L., and Porter, J. (2003). Social anxiety in childhood: the relationship with self and observer rated social skills. *J. Child Psychol. Psychiatry* 44, 737–742. doi: 10.1111/1469-7610.00159

Cartwright-Hatton, S., Tschernitz, N., and Gomersall, H. (2005). Social anxiety in children: social skills deficit, or cognitive distortion? *Behav. Res. Ther.* 43, 131–141. doi: 10.1016/j.brat.2003.12.003

Casey, B. J., Jones, R. M., and Somerville, L. H. (2011). Braking and accelerating of the adolescent brain. *J. Res. Adolesc.* 21, 21–33. doi: 10.1111/j.1532-7795.2010.00712.x

Chein, J., Albert, D., Brien, L. O., Uckert, K., and Steinberg, L. (2012). Peers increase adolescent risk taking by enhancing activity in the brain's reward ciruitry. *Dev. Sci.* 14, 1–16. doi: 10.1111/j.1467-7687.2010.01035

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Social Phobia—Diagnosis, Assessment, and Treatment*, eds R. G. Heimberg, M. Liebowitz, D. Hope, and F. Scheier (New York, NY: Guilford), 69–93.

Cohen Kadosh, K., Linden, D. E. J., and Lau, J. Y. (2013). Plasticity during childhood and adolescence: innovative approaches to investigating neurocognitive development. *Dev. Sci.* 16, 574–583. doi: 10.1111/desc.12054

Cooney, R. E., Atlas, L. Y., Joormann, J., Eugene, F., and Gotlib, I. H. (2006). Amygdala activation in the processing of neutral faces in social anxiety disorder: is neutral really neutral? *Psychiatry Res.* 148, 55–59. doi: 10.1016/j.pscychresns.2006.05.003

Creswell, C., Murray, L., and Cooper, P. (2013). Interpretation and expectation in childhood anxiety disorders: age effects and social specificity. *J. Abnorm. Child Psychol.* doi: 10.1007/s10802-013-9795-z. [Epub ahead of print].

Creswell, C., Woolgar, M., Cooper, P., Giannakakis, A., Schofield, E., Young, A. W., et al. (2008). Processing of faces and emotional expressions in infants at risk of social phobia. *Cogn. Emot.* 22, 437–458. doi: 10.1080/02699930701872392

Crone, E. A., and Dahl, R. E. (2012). Understanding adolescence as a period of social- affective engagement of goal flexibility. *Nat. Rev. Neurosci.* 13, 636–650. doi: 10.1038/nrn3313

Dennis, E. L., Jahanshad, N., McMahon, K. L., de Zubicaray, G. I., Martin, N. G., Hickie, I. B., et al. (2013). Development of brain structural connectivity between ages 12 and 30: a 4-Tesla diffusion imaging study in 439 adolescents and adults. *Neuroimage* 64, 671–684. doi: 10.1016/j.neuroimage.2012.09.004

Ernst, M., Nelson, E. E., Jazbec, S., McClure, E. B., Monk, C. S., Leibenluft, E., et al. (2005). Amygdala and nucleus accumbens in responses to receipt and omission of gains in adults and adolescents. *Neuroimage* 25, 1279–1291. doi: 10.1016/j.neuroimage.2004.12.038

Gajados, Z. K., Henderson, K. D., Hirschhorn, J. N., and Palmert, M. R. (2010). Genetic determinants of pubertal timing in the general population. *Mol. Cell Endocrinol.* 324, 21–29. doi: 10.1016/j.mce.2010.01.038

Galvan, A., Hare, T. A., Parra, C. E., Penn, J., Voss, H., Glover, G., et al. (2006). Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *J. Neurosci.* 26, 6885–6892. doi: 10.1523/JNEUROSCI.1062-06.2006

Gee, D. G., Humphreys, K. L., Flannery, J. F., Goff, B. F., Telzer, E. H., Shapiro, M., et al. (2013). A developmental shift from positive to negative connectivity in human amygdala–prefrontal circuitry. *J. Neurosci.* 33, 4584–4593. doi: 10.1523/JNEUROSCI.3446-12.2013

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., et al. (1999). Brain development during childhood and adolescence: a longitudinal MRI study. *Nat. Neurosci.* 2, 861–863.

Goddings, A. L., Mills, K. L., Clasen, L. S., Giedd J. N., Viner, R. M., and Blakemore, S. J. (2013). The influence of puberty on subcortical brain development. *Neuroimage*. doi: 10.1016/j.neuroimage.2013.09.073. [Epub ahead of print].

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., et al. (2004).

Dynamic mapping of human cortical development during childhood through early adulthood. *Proc. Natl. Acad. Sci. U.S.A.* 101, 8174–8179. doi: 10.1073/pnas.0402680101

Gunther Moor, B., Güroglu, B., Op de Macks, Z. A., Rombouts, S. A. R. B., Van der Molen, M. W., and Crone, E. A. (2012). Social exclusion and punishment of excluders: neural correlates and developmental trajectories. *Neuroimage* 59, 708–717. doi: 10.1016/j.neuroimage.2011.07.028

Gunther Moor, B., Macks, Z. A., Güroglu, B., Rombouts, S. A., Molen, M. W., and Crone, E. A. (2011). Neurodevelopmental changes of reading the mind in the eyes. *Soc. Cogn. Affect. Neurosci.* 7, 44–52. doi: 10.1093/scan/nsr020

Gunther Moor, B., van Leijenhorst, L., Rombouts, S. A., Crone, E. A., and van der Molen, M. W. (2010). Do you like me? Neural correlates of social evaluation and developmental trajectories. *Soc. Neurosci.* 5, 461–482. doi: 10.1080/17470910903526155

Guroglu, B., van den Bos, W., van Dijk, E., Rombouts, S. A., and Crone, E. A. (2011). Dissociable brain networks involved in development of fairness considerations: understanding intentionality behind unfairness. *Neuroimage* 57, 634–641. doi: 10.1016/j.neuroimage.2011.04.032

Guyer, A. E., Benson, B., Choate, V. R., Bar-Haim, Y., Perez-Edgar, K., Jarcho, J. M., et al. (2014). Lasting associations between early-childhood temperament and late-adolescent reward-circuitry response to peer feedback. *Dev. Psychopathol.* 26, 229–243. doi: 10.1017/S0954579413000941

Guyer, A. E., Lau, J. Y. F., McClure-Tone, E. B., Parrish, J., Shiffrin, N. D., Reynolds, R. C., et al. (2008). Amygdala and ventrolateral prefrontal cortex function during anticipated peer evaluation in pediatric social anxiety. *Arch. Gen. Psychiatry* 65, 1303–1312. doi: 10.1001/archpsyc.65.11.1303

Hare, T., Tottenham, N., Galvan, A., Voss, H. U., Glover, G. H., and Casey, B. J. (2008). Biological substrates of emotional reactivity and regulation in adolescence during an emotional go-nogo task. *Biol. Psychiatry* 63, 927–934. doi: 10.1016/j.biopsych.2008.03.015

In-Albon, T., Dubi, K., Rapee, R. M., and Schneider, S. (2009). Forced choice reaction time paradigm in children with separation anxiety disorder, social phobia, and nonanxious controls. *Behav. Res. Ther.* 47, 1058–1065. doi: 10.1016/j.brat.2009.08.003

Jarcho, J. M., Leibenluft, E., Walker, O. L., Fox, N. A., Pine, D. S., and Nelson, E. E. (2013). Neuroimaging studies of pediatric social anxiety: paradigms, pitfalls and a new direction for investigating the neural mechanisms. *Biol. Mood Anxiety Disord.* 3, 14. doi: 10.1186/2045-5380-3-14

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., and Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV in the national comorbidity survey replication. *Arch. Gen. Psychiarty* 62, 593–768. doi: 10.1001/archpsyc.62.6.593

Killgore, W. D. S., and Jurgelun-Todd, D. (2005). Social anxiety predicts amydala activation in adolescents viewing fearful faces. *Neuroreport* 16, 1671–1675. doi: 10.1097/01.wnr.0000180143.99267.bd

Lau, J. Y. (2013). Cognitive bias modification of interpretations: a viable treatment for child and adolescent anxiety? *Behav. Res. Ther.* 51, 614–622. doi: 10.1016/j.brat.2013.07.001

Lau, J. Y., Britton, J. C., Nelson, E. E., Angold, A., Ernst, M., Goldwin, M., et al. (2011). Distinct neural signatures of threat learning in adolescents and adults. *Proc. Natl Acad. Sci. U.S.A.* 108, 4500–4505. doi: 10.1073/pnas.1005494108

Lerner, R. M., and Steinberg, L. (2004). *Handbook of Adolescent Psychology.* New Jersey: John Wiley and Sons. doi: 10.1002/9780471726746

Masten, C. L., Eisenberger, N. I., Borofsky, L. A., Pfeifer, J. H., McNealy, K., Mazziotta, J. C., et al. (2009). Neural correlates of social exclusion during adolescence: understanding the distress of peer rejection. *Soc. Cogn. Affect. Neurosci.* 4, 143–157. doi: 10.1093/scan/nsp007

McRae, K., Gross, J. J., Weber, J., Robertson, E. R., Sokol-Hessner, P., Ray, R. D., et al. (2012). The development of emotion regulation: an fMRI study of cognitive reappraisal in children, adolescents and young adults. *Soc. Cogn. Affect. Neurosci.* 7, 11–22. doi: 10.1093/scan/nsr093

Miers, A. C., Blöte, A. W., Bögels, S. M., and Westenberg, P. M. (2008). Interpretation bias and social anxiety in adolescents. *J. Anxiety Disord.* 22, 1462–1471. doi: 10.1016/j.janxdis.2008.02.010

Mills, K. L., Lalonde, F., Clasen, L. S., Giedd, J. N., and Blakemore, S. J. (2014). Developmental changes in the structure of the social brain in late childhood and adolescence. *Soc. Cogn. Affect. Neurosci.* 9, 123–131. doi: 10.1093/scan/nss113

Monk, C. S., McClure, E. B., Nelson, E. E., Zarahn, E., Bilder, R. M., Leibenluft, E., et al. (2003). Adolescent immaturity in attention-related brain engagement to emotional facial expressions. *Neuroimage*, 20, 420–428. doi: 10.1016/S1053-8119(03)00355-0

Nelson, E. E., Leibenluft, E., McClure, E. B., and Pine, D. S. (2005). The social re-orientation of adolescence: a neuroscience perspective on the process and its relation to psychopathology. *Psychol. Med.* 35, 163–174. doi: 10.1017/S0033291704003915

Ollendick, T. H., and Hirshfeld-Becker, D. R. (2002). The developmental psychopathology of social anxiety disorder. *Biol. Psychiatry* 51, 44–58. doi: 10.1016/S0006-3223(01)01305-1

Pass, L., Arteche, A., Cooper, P., Creswell, C., and Murray, L. (2012). Doll Play narratives about starting school in children of socially anxious mothers, and their relation to subsequent child school-based anxiety. *J. Abnorm. Child Psychol.* 40, 1375–1384. doi: 10.1007/s10802-012-9645-4

Paus, T., Zijdenbos, A., Worsley, K., Collins, D. L., Blumenthal, J., Giedd, J. N., et al. (1999). Structural maturation of neural pathways in children and adolescents: *in vivo* study. *Science* 283, 1908–1911.

Pérez-Edgar, K., Roberson-Nay, R., Hardin, M. G., Poeth, K., Guyer, A. E., Nelson, E. E., et al. (2007). Attention alters neural responses to evocative faces in behaviorally inhibited adolescents. *Neuroimage* 35, 1538–1546. doi: 10.1016/j.neuroimage.2007.02.006

Pfeifer, J. H., and Blakemore, S. J. (2012). Adolescent social cognitive and affective neuroscience: past, present, and future. *Soc. Cogn. Affect. Neurosci.* 7, 1–10. doi: 10.1093/scan/nsr099

Pfeifer, J. H., Masten, C. L., Moore, W. E., Oswald, T. M., Mazziotta, J. C., Iacoboni, M., et al. (2011). Entering adolescence: resistance to peer influence, risky behavior, and neural changes in emotion reactivity. *Neuron* 69, 1029–1036. doi: 10.1016/j.neuron.2011.02.019

Pitskel, N. B., Bolling, D. Z., Kaiser, M. D., Crowley, M. J., and Pelphrey, K. A., (2011). How grossed out are you? The neural bases of emotion regulation from childhood to adolescence. *Dev. Cogn. Neurosci.* 1, 324–337. doi: 10.1016/j.dcn.2011.03.004

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioural model of anxiety in Social Phobia. *Behav. Res. Ther.* 35, 741–756.

Roy, K. A., Vasa, R. A., Bruck, M., Mogg, K., Bradley, B. P., Sweeney, M., et al. (2008). Attention bias toward threat in pediatric anxiety disorders. *J. Am. Acad. Child Adolesc. Psychiatry* 47, 1189–1196. doi: 10.1097/CHI.0b013e3181825ace

Sisk, C. L., and Foster, D. L. (2004). The neural basis of puberty and adolescence. *Nat. Neurosci.* 7, 1040–1047. doi: 10.1038/nn1326

Somerville, L. H., Hare, T., and Casey, B. J. (2011). Frontostriatal maturation predict cognitive control failure to appetitive cues in adolescents. *J. Cogn. Neurosci.* 23, 2123–2134. doi: 10.1162/jocn.2010.21572

Sowell, E. R., Thompson, P. M., Holmes, C. J., Jernigan, T. L. and Toga, A. W. (1999). *In vivo* evidence for post-adolescent brain maturation in frontal and striatal regions. *Nat. Neurosci.* 2, 859–861.

Stirling, L. J., Eley, T. C., and Clark, D. M. (2006). Preliminary evidence for an association between social anxiety symptoms and avoidance of negative faces in school-age children. *J. Clin. Child Adolesc. Psychol.* 35, 440–445. doi: 10.1207/s15374424jccp3503_9

Van den Bos, W., van Dijk, E., Westenberg, M., Rombouts, S. A., and Crone, E. A. (2011). Changing brains, changing perspectives: the neurocognitive development of reciprocity. *Psychol. Sci.* 22, 60–70. doi: 10.1177/0956797610391102

Van Leijenhorst, L., Zanolie, K., Van Meel, C. S., Westenberg, P. M., Rombouts, S. A. R. B., and Crone, E. A. (2010). What motivates the adolescent? Brain regions mediating reward sensitivity across adolescence. *Cereb. Cortex* 20, 61–69. doi: 10.1093/cercor/bhp078

Wang, A. T., Lee, S. S., Sigman, M., and Dapretto, M. (2006). Developmental changes in the neural basis of interpreting communicative intent. *Soc. Cogn. Affect. Neurosci.* 1, 107–121. doi: 10.1093/scan/nsl018

Waters, A. M., Craske, M. G., Bergman, R. L., and Treanor, M. (2008). Threat interpretation bias as a vulnerability factor in childhood anxiety disorders. *Behav. Res. Ther.* 46, 39–47. doi: 10.1016/j.brat.2007.10.002

Wittchen, H. U., Stein, M. B., and Kessler, R. C. (1999). Social fears and social phobia in a community sample of adolescents and young adults: prevalence, risk factors and co-morbidity. *Psychol. Med.* 29, 309–323.

Yurgelun-Todd, D. A, and Killgore, W. D. S. (2006). Fear-related activity in the prefrontal cortex increases with age duringadolescence: a preliminary fMRI study. *Neurosci. Lett.* 406, 194–199. doi: 10.1016/j.neulet.2006.07.046

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Socially anxious individuals with low working memory capacity could not inhibit the goal-irrelevant information

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Socially anxious individuals are interfered by distractors. Recent work has suggested that low working memory capacity and inappropriate temporary goal induce attention to distractors. We investigated the effects of working memory capacity and temporary goal on attention to distractors in social anxiety. Participants viewed a rapid serial visual presentation, in which participants reported the identity of a single target letter drawn in red. Distractors appeared before the target was presented. When the color of distractors was red (i.e., goal-relevant stimuli), low-capacity individuals were strongly interfered by the distractors compared to high-capacity individuals regardless of social anxiety. When the color of distractors was goal-irrelevant, low-capacity and high socially anxious individuals were strongly interfered by the distractors. These results suggest that socially anxious individuals with low working memory capacity could not inhibit the goal-irrelevant information and direct attention to distractors.

Keywords: social anxiety, visual working memory capacity, goal setting, spatial blink, selective attention

INTRODUCTION

Anxious and socially anxious individuals tend to be more easily distracted by irrelevant stimuli. Although several previous studies have shown attentional prioritization of threatening distractors (e.g., threatening words, angry faces) among individuals with anxiety (Fox et al., 2005; Bar-Haim et al., 2007), recent research has shown that anxious and socially anxious individuals process non-emotional distractors as well (Derakshan et al., 2009; Moriya and Tanno, 2009a, 2010, 2011a; Ansari and Derakshan, 2010, 2011a,b; Sadeh and Bredemeier, 2011; Moser et al., 2012; Berggren and Derakshan, 2013). For example, Moriya and Tanno (2010) had participants search for a target letter (X or N) presented on an imaginary circle at a central fixation with a peripheral distractor. Although participants did not need to direct their attention toward the peripheral distractor, individuals high in social anxiety were more likely to attend to the distractor. Reaction times for the target were delayed for individuals high in social anxiety due to distractor interference. Few studies, however, have investigated why anxious and socially anxious individuals are distracted by irrelevant, non-emotional stimuli. In the present study, we focused on two important factors: visual working memory capacity (VWMC) and goal setting, both of which influence non-emotional distractor processing. We investigated the effects of these factors on distractor interference in individuals with social anxiety.

Previous studies have investigated individual differences in distractor processing, and suggest that individual differences in VWMC reflect spatial attention to distractors (Fukuda and Vogel, 2009, 2011). VWMC refers to the number of items an individual can represent in an on-line state; it is a limited ability (Luck and Vogel, 1997; Vogel and Machizawa, 2004; Awh et al., 2007). Several studies have suggested that individuals with low VWMC have poor attentional control and have difficulty filtering distractors (Vogel et al., 2005; McNab and Klingberg, 2008; Fukuda and Vogel, 2009, 2011). For instance, Fukuda and Vogel (2009, 2011) had participants perform a change detection task that measured VWMC while performing a visual task (e.g., spatial-blink task, visual search task) with a salient, to-be-ignored distractor. Individuals with low VWMC had difficulty filtering out distractors, and target detection performance subsequently suffered. Considering these previous results, we hypothesize that anxious and socially anxious individuals have low VWMC, which leads to distractor interference.

Interestingly, however, social anxiety is not necessarily associated with low VWMC. This association depends on the components of working memory. Social anxiety is negatively correlated with phonological working memory capacity (Amir and Bomyea, 2011; Visu-Petra et al., 2011), but positively correlated with VWMC (Moriya and Sugiura, 2012). According to Fukuda and Vogel (2009, 2011), enhanced distractor interference is associated with low VWMC. According to these results, socially anxious individuals with high VWMC should be able to efficiently filter out distractors. This, however, is inconsistent with previous research showing that anxious and socially anxious individuals do not ignore distractors (Derakshan et al., 2009; Moriya and Tanno, 2009a, 2010, 2011a; Ansari and Derakshan, 2010, 2011a,b; Sadeh and Bredemeier, 2011; Moser et al., 2012; Berggren and Derakshan, 2013). To address this issue, we need to assess the interactive effects of social anxiety and VWMC on distractor processing. Several previous studies have shown that cognitive control moderates the attentional prioritization of threatening distractors in anxiety, and an attentional bias toward threatening distractors has been observed among highly anxious individuals with low cognitive control (Derryberry and Reed, 2002;

Peers and Lawrence, 2009; Reinholdt-Dunne et al., 2009; Susa et al., 2012). Thus, we predict that VWMC also moderates the interference of non-emotional distractors in social anxiety. In the present study, therefore, we investigated the interaction effect of VWMC and social anxiety on non-emotional distractor processing.

Distractor interference also depends on goal setting. When people set their goals for a specific feature (e.g., a red stimulus), a stimulus that has the same feature(s) as the goal(s) strongly attracts attention (Folk et al., 1992, 1994, 2002; Lamy et al., 2004; Anderson and Folk, 2012). Attentional priority is fully contingent on the top-down goal settings adopted by the observer, and goal-irrelevant distractors are simply suppressed. For example, in a study by Folk et al. (2002), participants viewed a central rapid serial visual presentation (RSVP), in which a target letter was defined as a particular color (e.g., red). Participants needed to detect a target letter while distractor letters were occasionally presented in the periphery prior to the presentation of the target. In this case, the red item comprised the attentional set. Attention to the peripheral distractors led to a decrement in target detection, in a phenomenon known as a *spatial blink*. When the color of the distractors differed from that of the target (e.g., target color was red and distractor color was blue), the effect of the spatial blink was still observed, but it was small. Although salient distractors attract attention (Theeuwes, 1992), goal-irrelevant distractors appear to have little ability to attract attention. On the other hand, when a distractor whose color matched the target's color (e.g., both target and distractor color is red) was presented prior to the target's appearance, the distractor captured attention, and the accuracy of target detection decreased; this decrement was much larger than in the case of goal-irrelevant distractors. Goal-relevant distractors strongly attracted attention compared to goal-irrelevant distractors. Moreover, attention to the goal-relevant distractors has been observed especially in individuals with low VWMC (Fukuda and Vogel, 2009). While attention to goal-irrelevant distractors derives from saliency, attention to goal-relevant distractors additionally depends on top-down control. It is, therefore, possible that anxious individuals' goals have an effect on distractor processing.

A few previous studies have already shown the effects of goals on attentional priority in anxiety. Vogt et al. (2013) revealed an important role of goals on distractor processing in anxiety, even though the authors used emotional distractors. In this study, participants were asked to perform a dual task – a dot-probe task and a goal task – during each trial. During the goal task, participants were required to detect a specific picture (a goal-relevant picture) and respond as quickly as possible. During the dot-probe task, two pictures were presented simultaneously; immediately after the pictures disappeared, a probe appeared in one of two locations (either the same or opposite side of the preceding picture). Participants were asked to detect the location of the probe as quickly as possible. Notably, the goal-relevant picture was presented during the dot-probe task, even though it did not predict a probe location. When the goal-relevant picture and a threatening picture were presented simultaneously, highly anxious individuals did not direct attention toward the threatening stimulus but, rather, toward the goal-relevant picture. These results indicated that anxious individuals did not show distractor processing if their goal was to detect a specific target. Because Vogt et al. (2013) used emotional distractors, it is still unclear whether goals influence non-emotional distractor processing in social anxiety. Another open question is whether the effects of goals on distractor interference are influenced by VWMC.

In the present study, we investigated the effects of VWMC and goals on distractor processing in social anxiety. We focused on social anxiety because socially anxious individuals are hypervigilant to non-emotional visual information (Moriya and Tanno, 2009b), and cognitive control is strongly associated with trait social anxiety (Moriya and Tanno, 2008). In the present experiments, we used a spatial-blink task (Folk et al., 2002; Fukuda and Vogel, 2009). As mentioned above, we can measure the degree of attentional effects to distractors by target detection decrements, or *the spatial blink*. Previous studies have shown that the peripheral distractor produces a reduction in target identification accuracy when the distractor shares a target color (i.e., goal-relevant distractor) compared to when the color of the distractor differs from that of the target (Folk et al., 2002; Fukuda and Vogel, 2009). During this task, we can investigate the effects of goal setting on distractor processing. Fukuda and Vogel (2009) also showed that individuals with low VWMC had a large decrement in target detection during this task. The spatial-blink task is appropriate for investigating the interaction between VWMC and goals on distractor processing.

Our hypotheses were as follows. Basing our hypotheses on the results of Vogt et al. (2013), we assumed that participants would direct attention toward goal-relevant distractors regardless of whether they had social anxiety. Considering that individuals with low VWMC are hindered by goal-relevant distractors (Fukuda and Vogel, 2009), a decrement in target identification accuracy may be negatively correlated with VWMC, regardless of social anxiety (Hypothesis 1). However, for goal-irrelevant distractors, individuals high in social anxiety and low in VWMC may process distractors, since previous studies have shown that impaired cognitive control in anxiety increases attentional prioritization of goal-irrelevant distractors (Derryberry and Reed, 2002; Peers and Lawrence, 2009; Reinholdt-Dunne et al., 2009; Susa et al., 2012). Therefore, we hypothesized that when presented with goal-irrelevant distractors, a decrement in target identification may not be simply correlated with social anxiety, but may be associated with the interaction between social anxiety and VWMC (Hypothesis 2). Moreover, the decrement in target identification might be especially observed among individuals high in social anxiety but low in VWMC. The decrement in target identification may be bigger, along with the degree of social anxiety among individuals low in VWMC; however, this is unlikely to be the case among individuals high in VWMC (Hypothesis 3).

MATERIALS AND METHODS

PARTICIPANTS

Participants were 40 undergraduates (22 women) aged between 18 and 27 years (mean age = 19.5, SD = 2.0). Participants provided informed consent and had normal or corrected-to-normal vision.

STIMULI AND PROCEDURE

Change detection task for visual working memory capacity

Participants first performed a change detection task (Luck and Vogel, 1997; Vogel and Machizawa, 2004)[1]. All stimulus arrays were presented within a 9.8° × 7.3° region on a monitor with a gray background, and stimuli were placed at least 2.0° (center to center) apart. Within the memory array, participants were presented with brief arrays of 4, 8, or 12 colored squares (0.65° × 0.65°) for 100 ms and asked to remember the items. Each square was selected at random from a set of seven highly discriminable colors (red, blue, violet, green, yellow, black, and white), and a given color could appear no more than twice within a single array. Memory was tested 1 s later by using a test array that was either identical to the memory array, or different by one color. Participants were required to press one of two buttons to indicate whether the two arrays were identical or different. The color of one item in the test array differed from the corresponding item in the memory array on 50% of the trials; the memory and test arrays were otherwise identical. Stimulus positions were randomized on each trial. There were 80 trials within each set size, providing participants with a total of 240 trials.

In order to investigate individual differences in memory capacity, we estimated each participant's VWMC by K-estimates according to a standard formula (Cowan, 2001), $K = S\,(H - F)$, where K is memory capacity, S is array size, H is observed hit rate, and F is false alarm rate. The hit rate is the proportion of correct responses when two arrays differ. The false alarm rate is the proportion of incorrect responses when two arrays are identical. K is computed in each set size. Considering that an average capacity of visual working memory is typically around three to four items (Luck and Vogel, 1997; Vogel and Machizawa, 2004), individual differences in VWMC might not be observed with low set sizes of less than four items. In order to capture individual differences, we focused on the average K-estimates for set sizes 8 and 12.

Spatial-blink task

After the change detection task, participants performed a spatial-blink task (Folk et al., 2002; Fukuda and Vogel, 2009). Participants observed a RSVP of colored letters (1.3° × 1.3°) presented at fixation (**Figure 1**). All the letters except for I, O, P, Q, and R were used to create a stream with 15 letters without repetition. One letter in the RSVP was red while the others were blue, green, yellow, or violet. Participants were required to identify a red letter – the target – in the RSVP. After a white fixation cross was presented in the middle of the screen for 500 ms, each letter was presented for 50 ms and followed by a 50-ms blank screen. For each RSVP, 15 letters were presented, and a target appeared equally often in positions 8 through 12 of the letter sequence.

There were four different distractor conditions. In the *no-distractor condition* (one-fourth of all trials), only central letters were presented, and each of the 15 frames in the RSVP contained only a central letter. In the distractor condition (three-quarters of all trials), four "#"s appeared 5.2° above, below, to the right,

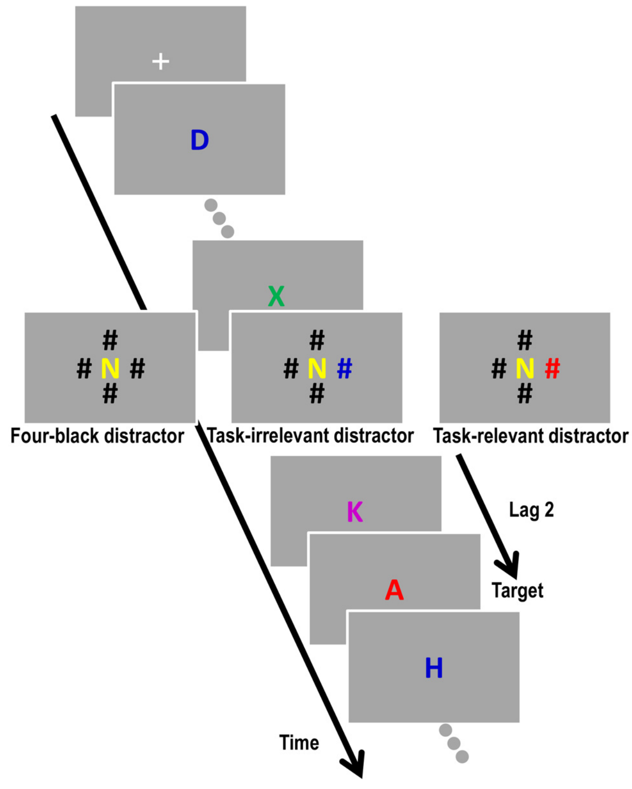

FIGURE 1 | Sequence of the spatial-blink task with a distractor-target lag of 2.

and to the left of a central letter, simultaneously with a target, or one, two, or three frames before the target letter. Depending on the distractor condition, the color of the "#"s differed. In the *four-black distractor condition* (one-third of the distractor trials), four black "#"s appeared. In the *goal-irrelevant distractor condition* (one-third of the distractor trials), three black "#"s and one colored "#" appeared. The colored "#" differed from the color of the target (blue, green, yellow, or violet). In the *goal-relevant distractor condition* (one-third of the distractor trials), three black "#"s and one red "#" appeared. That is, one of the "#"s was the same color as the target. The colored "#" was presented equally often in the four possible locations. Four-distractor conditions appeared randomly and equally often. Trials with four possible lags between the presentation of the target and the presentation of the distractors also appeared randomly and equally often. There were 80 trials within each distractor condition, providing participants with a total of 320 trials.

Both tasks were conducted on a 17-inch monitor. The experiments were programed using MATLAB equipped with the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). The viewing distance was about 60 cm.

Questionnaire

At the end of the task, participants completed the Japanese version of the Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983; Sasagawa et al., 2004). The BFNE assesses apprehension related to

[1]Data related to visual working memory capacity in the present study is part of data obtained from a previous study (Moriya and Sugiura, 2012). However, in that study, we did not analyze the data with the results of a spatial-blink task.

others' negative evaluations and reflects one's level of social anxiety. The scale consists of 12 items rated on 5-point Likert scales. The scale has high internal consistency (Cronbach's alpha = 0.92) and high test–retest reliability with a 3-month interval ($r = 0.74$; Sasagawa et al., 2004).

RESULTS

The mean percentages of correct target identifications within each distractor condition are presented in **Figure 2**. We used 4 (Distractor: no-distractor, four-black distractor, goal-irrelevant distractor, and goal-relevant distractor) × 4 (Lag: 0, 1, 2, and 3) ANOVAs to ascertain spatial blink. The analysis showed significant main effects of Distractor, $F(3,117) = 87.57$, $p < 0.001$, $\eta^2 = 0.69$, and Lag, $F(3,117) = 40.99$, $p < 0.001$, $\eta^2 = 0.51$. The two-way interaction was also significant, $F(9,351) = 15.14$, $p < 0.001$, $\eta^2 = 0.28$. Further analyses revealed that under the four-black and goal-irrelevant distractor conditions, the mean percentages of correct identification were significantly lower at lags 1 and 2 than at lags 0 and 3 (p values < 0.01). Under the goal-relevant distractor conditions, the mean percentages of correct identification were also significantly lower at lags 1, 2, and 3 than at lag 0 (p values < 0.01). Moreover, the correct percentages at lag 2 were significantly lower than were those at lags 1 and 3 (p values < 0.01). The correct percentages under four-black and goal-irrelevant distractor conditions at lags 1 and 2 and goal-relevant distractor conditions at lags 1, 2, and 3 were significantly lower than were those under the no-distractor conditions (p values < 0.01). Specifically, correct target identification under the goal-relevant distractor condition at lag 2 was lower than during any other condition (p values < 0.01). These results suggest that spatial blink was observed in the present experiment, especially under the goal-relevant condition at lag 2.

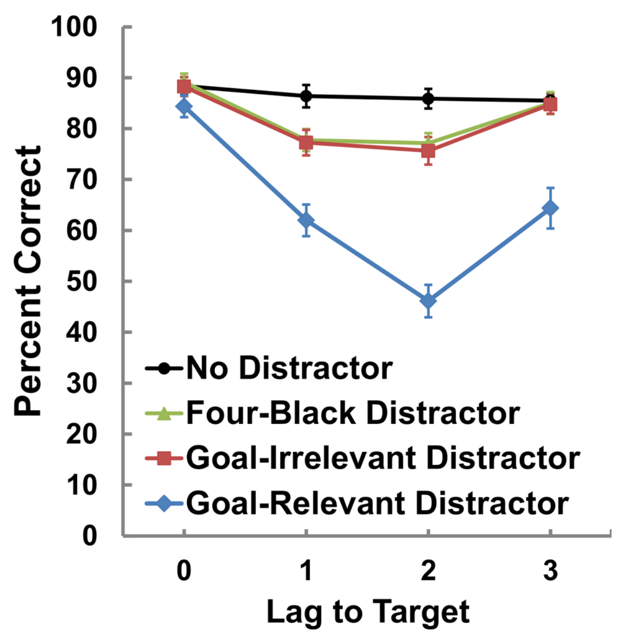

FIGURE 2 | Mean percentages of correct target identification.

We evaluated the decrement in target identification (i.e., the spatial-blink effect) by subtracting correct percentages under each distractor condition at lag 2 from the average correct percentages under the no-distractor condition. Next, we analyzed correlations between social anxiety, VWMC, and the effects of spatial blink on each distractor condition to investigate whether the decrement in target identification was negatively correlated with VWMC for goal-relevant distractors (Hypothesis 1), and not correlated with social anxiety for goal-irrelevant distractors (Hypothesis 2). Correlations are presented in **Table 1**. Social anxiety was positively correlated with VWMC. The spatial-blink effect under the four-black distractor condition was positively correlated with the spatial-blink effect under the goal-irrelevant and goal-relevant distractor conditions. Notably, the spatial-blink effect under the goal-relevant distractor condition was negatively correlated with VWMC. Individuals with high VWMC could inhibit spatial blink by goal-relevant distractors. However, social anxiety did not correlate with spatial blink under any other condition.

We also analyzed partial correlations between social anxiety, VWMC, and the effects of spatial blink when controlling for social anxiety and VWMC, respectively (**Table 2**). When controlling for social anxiety, VWMC was marginally correlated with the spatial-blink effect under the goal-relevant distractor condition, but was not clearly significant, $r = -0.31$, $p = 0.059$. When controlling for VWMC, social anxiety was not significantly correlated with the spatial-blink effect under the goal-irrelevant distractor condition, although it was marginally significant, $r = 0.29$, $p = 0.074$.

To investigate the interaction effects between social anxiety and VWMC on the decrement in target identification for goal-irrelevant distractors (Hypothesis 2), we focused on the moderating role of working memory capacity on the link between social anxiety and spatial blink. We applied general linear models predicting spatial-blink effects by social anxiety and working memory capacity. First, all independent variables were centered on the grand mean, because mean centering has interpretational and computational advantages (Aiken and West, 1991; Bauer and Curran, 2005). In Step 1 (main effects), social anxiety scores and VWMC were entered, and then in Step 2 (interaction effect), the social anxiety × memory capacity interaction was entered for each distractor condition. The results of the regression analysis are shown in **Table 3**. Under the four-black and goal-relevant distractor conditions, there were no significant main effects or any interaction effects. Under the goal-irrelevant distractor condition, the main effect was not significant. However, the interaction was significant, as was the model, $F(3,36) = 3.46$, $R^2 = 0.22$, $p < 0.05$. The interaction is depicted in **Figure 3** using a simple slope analysis at one SD above and below the mean VWMC (Preacher et al., 2006) in order to examine whether the decrement in target identification increases along with the degree of social anxiety among individuals low in VWMC (Hypothesis 3). The simple slope for high VWMC was significant ($B = 0.98$, $\beta = 0.61$, $t = 2.99$, $p < 0.01$) whereas that for low VWMC was not ($B = -0.08$, $\beta = -0.05$, $t = -0.23$, $p > 0.80$).

DISCUSSION

In the present experiment, we investigated the effects of VWMC and goals on distractor processing in individuals with social

Table 1 | Mean values, standard deviations, and correlations among social anxiety, visual working memory capacity, and decreased percentages of target identification.

	VWMC	Four-black	Goal-irrelevant	Goal-relevant	Average	SD
Social anxiety	0.35*	0.23	0.25	−0.08	40.7	8.5
VWMC	–	−0.02	−0.09	−0.33*	3.9	1.1
Four-black		–	0.50**	0.33*	10.5	12.3
Goal-irrelevant			–	0.17	10.9	13.1
Goal-relevant				–	40.4	19.8

**p < 0.05, **p < 0.01.*
VWMC, visual working memory capacity; four-black, four-black distractor condition; goal-irrelevant, goal-irrelevant distractor condition; goal-relevant, goal-relevant distractor condition.

Table 2 | Partial correlations controlling for social anxiety and visual working memory capacity.

	Social anxiety	Four-black	Goal-irrelevant	Goal-relevant
VWMC	–	−0.25	−0.25	−0.31
Four-black	0.15	–	0.44**	0.33*
Goal-irrelevant	0.29	0.43**	–	0.20
Goal-relevant	0.01	0.27	0.13	–

**p < 0.05, **p < 0.01.*
Partial correlations controlling for social anxiety are above the diagonal and partial correlations controlling for visual working memory capacity are below the diagonal.

anxiety. Our results showed that regardless of the degree of social anxiety, individuals with low VWMC had difficulty in inhibiting the processing of goal-relevant distractors. For goal-irrelevant distractors, however, we found an interaction between VWMC and social anxiety. Individuals with high social anxiety and low VWMC showed strong interference from goal-irrelevant distractors, whereas individuals with high social anxiety and high VWMC, and individuals with low social anxiety, did not show strong interference. Even under non-color distractor trials (i.e., four-black distractor trials), participants showed a decrement in target identification accuracy compared to the no-distractor trials, although this decrement was not associated with social anxiety and VWMC. When presented with goal-irrelevant but salient colored distractors under goal-irrelevant conditions, socially anxious individuals with low VWMC had difficulty filtering out distractors.

Under goal-relevant distractor conditions, attention to distractors was associated with low VWMC, regardless of the degree of social anxiety. This result is consistent with previous research (Fukuda and Vogel, 2009, 2011) and our hypothesis (Hypothesis 1). Individuals with low VWMC could not filter out the goal-relevant distractors efficiently. Because attention may be allocated to the location of peripheral distractors for some time, these individuals miss the central target, which is presented soon after the onset of the distractors. However, the association between VWMC and attention to goal-relevant distractors was not clearly observed when controlling for the degree of social anxiety. Considering that the main effect of multiple regression analysis under the goal-relevant condition was not significant (either when entering social anxiety, or VWMC), attention to goal-relevant distractors was influenced by social

Table 3 | Summary of the hierarchical regression analysis for social anxiety and visual working memory capacity predicting the effects of spatial blink on each distractor condition.

	Four-black				Goal-irrelevant				Goal-relevant			
	B	**SE *B***	**β**	**Δ*R*²**	***B***	**SE *B***	**β**	**Δ*R*²**	***B***	**SE *B***	**β**	**Δ*R*²**
Step 1				0.07				0.11				0.10
SA	0.19	0.21	0.16		0.49	0.27	0.31		0.02	0.40	0.01	
VWMC	−2.58	1.61	−0.27		−3.28	2.07	−0.26		−6.11	3.13	−0.32	
Step 2				0.04				0.11*				0.02
SA	0.18	0.20	0.14		0.45	0.25	0.28		0.04	0.41	0.02	
VWMC	−3.34	1.69	−0.35		−4.91	2.08	−0.39*		−5.23	3.35	−0.28	
SA × VWMC	−0.24	0.18	−0.23		−0.51	0.22	−0.37*		0.28	0.35	0.13	
Total R^2				0.11				0.22*				0.12

**p < 0.05, SA, social anxiety.*

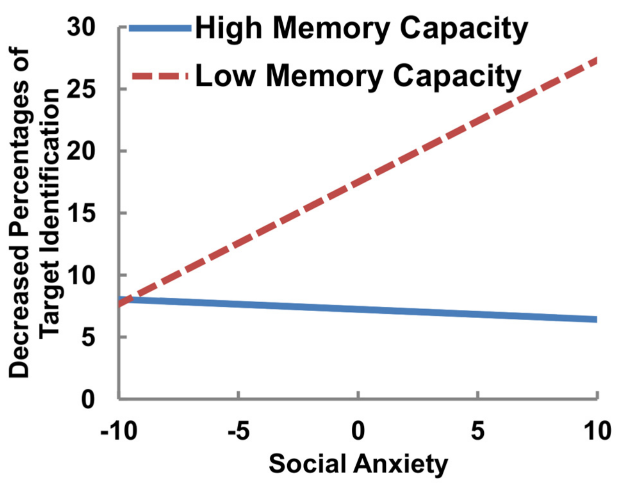

FIGURE 3 | Conditional associations between social anxiety and decreased percentages of target identification for high and low visual working memory capacity.

anxiety. However, because the partial correlation between social anxiety and the decrement in target identification under the goal-relevant condition did not reach significance, and the regression coefficient of social anxiety was too small, social anxiety alone may have little effect on attention to goal-relevant distractors.

Social anxiety itself was not correlated with goal-irrelevant distractor processing; socially anxious individuals with low VWMC, however, did show goal-irrelevant distractor processing. This is consistent with our hypotheses (Hypotheses 2 and 3). Previous studies have shown that socially anxious individuals experience interference from distractor stimuli, whereas impaired cognitive control among individuals with anxiety moderates interference from threatening distractors (Derryberry and Reed, 2002; Peers and Lawrence, 2009; Reinholdt-Dunne et al., 2009; Susa et al., 2012). In some studies, however, VWMC – being an aspect of cognitive control – was not diminished but enhanced among individuals with social anxiety (Moriya and Sugiura, 2012). Therefore, we were interested in assessing the interactive effects of social anxiety and VWMC on distractor interference. The present results showed that even highly socially anxious individuals with high VWMC could efficiently filter out goal-irrelevant distractors, but individuals with high social anxiety and low VWMC could not.

Social anxiety was not associated with distractor interference for goal-relevant distractors, but was associated with interference from goal-irrelevant distractors. According to Vogt et al. (2013), even anxious individuals direct attention toward goal-relevant stimuli. Our findings are consistent with their results. One difference in the present study was that socially anxious individuals with low VWMC could not suppress goal-irrelevant distractors, whereas in Vogt et al. (2013), highly anxious individuals did not attend to goal-irrelevant stimuli. This may have occurred due to differences in the study tasks. In Vogt et al.'s (2013) study, a goal-irrelevant stimulus was presented alongside a goal-relevant stimulus. While their results suggest that anxious individuals can direct attention to goal-relevant targets, such findings do not mean that their participants could suppress goal-irrelevant distractors. In the present study, we showed goal-relevant and goal-irrelevant distractors during each trial. The present results suggest that individuals high in social anxiety have difficulty filtering out goal-irrelevant distractors. However, socially anxious individuals may be able to reduce the effects of goal-irrelevant distractors if they have high VWMC.

However, in the four-black distractor trials, there was no interactive effect between social anxiety and VWMC on distractor interference. The four-black distractors were also goal-irrelevant distractors. Four letters were black during these trials, while one letter was colored in the goal-irrelevant distractor conditions. The colored letter was more salient compared to other three black letters. The salient distractor may attract attention for individuals with social anxiety. Previous studies have shown that anxious and socially anxious individuals are sensitive to non-emotional salient stimuli, and exogenously direct attention toward these distractors (Moriya and Tanno, 2009a; Moser et al., 2012). The present results suggest that socially anxious individuals with low VWMC experience interference from particularly salient distractors. Under the four-distractor conditions, only the central letter was colored, and distractors were not salient. Therefore, we did not find any effects of social anxiety on distractor interference under the four-distractor conditions.

The present results have valuable clinical implications. One of the key issues in social anxiety disorder is the processing of goal-irrelevant emotional distractors (Mogg et al., 2004). Because attentional maintenance to goal-irrelevant threatening stimuli increases anxiety, many clinical researchers are optimistic about the potential use of attentional bias modification, in which individuals with social anxiety disorder are trained to disengage attention from goal-irrelevant threatening stimuli (Schmidt et al., 2009). However, it is difficult to disengage or avert attention from goal-irrelevant threatening stimuli. The present results showed the possibility that increasing VWMC is a useful training method for efficient disengagement from goal-irrelevant threatening stimuli. In the present results, even highly socially anxious individuals could ignore the goal-irrelevant stimuli if they were also had high VWMC. Although further research must be undertaken to reveal whether the present results are observed for goal-irrelevant *emotional* distractors, it would also be valuable to investigate whether increasing VWMC in clinical samples could enhance suppression of goal-irrelevant distractors and decrease their anxiety.

Although this is the first study to show the interactive effects of VWMC and social anxiety on non-emotional distractor processing, some limitations should be noted. First, the present study demonstrated attentional processing of goal-irrelevant distractors in social anxiety with low VWMC, but we could not divide the effects of attentional capture to – vs. attentional disengagement from – goal-irrelevant distractors. Two possibilities are responsible for the present results. The first is that individuals with high social anxiety and high VWMC can resist attentional capture to goal-irrelevant distractors. The second is that individuals with high social anxiety and high VWMC also direct attention to goal-irrelevant distractors, but can efficiently disengage from these distractors. It is very important to investigate the effects of these two attentional systems, since such systems have different effects on generalized and social anxiety. Recent studies have shown impaired attentional disengagement in general anxiety and social anxiety (Fox et al., 2001, 2002; Yiend and Mathews, 2001; Amir et al., 2003; Georgiou et al., 2005; Koster et al., 2006; Moriya and Tanno, 2011b; Wieser et al., 2012). Considering our results together with such instances of previous research, we posit that individuals with high social anxiety and low VWMC do not disengage from goal-irrelevant distractors while showing a decrement in target identification. This interpretation is consistent with Fukuda and Vogel (2011), who showed that low VWMC was not related to attentional capture to distractors but, rather, impaired attentional disengagement from distractors. Future studies should assess these two different effects of attentional capture and disengagement on distractor processing in anxiety. Second, we did not investigate the effects of other scales (e.g., trait and state anxiety, depression) in the present study, and used a single measure of social anxiety. It is still unclear whether distractor processing is also influenced by the interaction between VWMC and, for example, trait anxiety. Many scales of negative emotionality should be used in future studies. Third, our sample size was not sufficient to investigate individual differences. Further studies should include a larger number of participants in order to corroborate the present results.

In summary, the present study investigated the effects of goal setting and VWMC on distractor processing during a spatial-blink task among socially anxious participants. Participants processed the goal-relevant distractors regardless of social anxiety, and displayed a spatial blink. For goal-irrelevant distractors, distractor processing was also observed, but this was associated with an interaction between VWMC and social anxiety. Individuals with high social anxiety but low VWMC exhibited strong distractor interference; meanwhile, those with high social anxiety and high VWMC, as well as those with low social anxiety, did not show strong interference. Although it is still unclear whether the present results are specific to social anxiety or any other negative emotionality (e.g., trait and state anxiety, depression), the present results indicate that it is important to consider the effects of goals and VWMC on distractor processing in social anxiety.

REFERENCES

Aiken, L. S., and West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions*, Vol. 45. Newbury Park, CA: Sage.

Amir, N., and Bomyea, J. (2011). Working memory capacity in generalized social phobia. *J. Abnorm. Psychol.* 120, 504–509. doi: 10.1037/a0022849

Amir, N., Elias, J., Klumpp, H., and Przeworski, A. (2003). Attentional bias to threat in social phobia: facilitated processing of threat or difficulty disengaging attention from threat? *Behav. Res. Ther.* 41, 1325–1335. doi: 10.1016/S0005-7967(03)00039-1

Anderson, B. A., and Folk, C. L. (2012). Dissociating location-specific inhibition and attention shifts: evidence against the disengagement account of contingent capture. *Atten. Percept. Psychophys.* 74, 1183–1198. doi: 10.3758/s13414-012-0325-9

Ansari, T. L., and Derakshan, N. (2010). Anxiety impairs inhibitory control but not volitional action control. *Cogn. Emot.* 24, 241–254. doi: 10.1080/02699930903381531

Ansari, T. L., and Derakshan, N. (2011a). The neural correlates of cognitive effort in anxiety: effects on processing efficiency. *Biol. Psychol.* 86, 337–348. doi: 10.1016/j.biopsycho.2010.12.013

Ansari, T. L., and Derakshan, N. (2011b). The neural correlates of impaired inhibitory control in anxiety. *Neuropsychologia* 49, 1146–1153. doi: 10.1016/j.neuropsychologia.2011.01.019

Awh, E., Barton, B., and Vogel, E. K. (2007). Visual working memory represents a fixed number of items regardless of complexity. *Psychol. Sci.* 18, 622–628. doi: 10.1111/j.1467-9280.2007.01949.x

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., and van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol. Bull.* 133, 1–24. doi: 10.1037/0033-2909.133.1.1

Bauer, D., and Curran, P. (2005). Probing interactions in fixed and multilevel regression: inferential and graphical techniques. *Multivariate Behav. Res.* 40, 373–400.

Berggren, N., and Derakshan, N. (2013). Attentional control deficits in trait anxiety: why you see them and why you don't. *Biol. Psychol.* 92, 440–446. doi: 10.1016/j.biopsycho.2012.03.007

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spat. Vis.* 10, 433–436. doi: 10.1163/156856897X00357

Cowan, N. (2001). The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behav. Brain Sci.* 24, 87–114. doi: 10.1017/S0140525X01003922

Derakshan, N., Ansari, T. L., Hansard, M., Shoker, L., and Eysenck, M. W. (2009). Anxiety, inhibition, efficiency, and effectiveness: an investigation using antisaccade task. *Exp. Psychol.* 56, 48–55. doi: 10.1027/1618-3169.56.1.48

Derryberry, D., and Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *J. Abnorm. Psychol.* 111, 225–236. doi: 10.1037//0021-843X.111.2.225

Folk, C. L., Leber, A. B., and Egeth, H. E. (2002). Made you blink! Contingent attentional capture produces a spatial blink. *Percept. Psychophys.* 64, 741–753. doi: 10.3758/BF03194741

Folk, C. L., Remington, R. W., and Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *J. Exp. Psychol. Hum. Percept. Perform.* 18, 1030–1044. doi: 10.1037/0096-1523.18.4.1030

Folk, C. L., Remington, R. W., and Wright, J. (1994). The structure of attentional control: contingent attentional capture by apparent motion, abrupt onset, and color. *J. Exp. Psychol. Hum. Percept. Perform.* 20, 317–329. doi: 10.1037/0096-1523.20.2.317

Fox, E., Russo, R., Bowles, R., and Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *J. Exp. Psychol. Gen.* 130, 681–700. doi: 10.1037//0096-3445.130.4.681

Fox, E., Russo, R., and Dutton, K. (2002). Attentional bias for threat: evidence for delayed disengagement from emotional faces. *Cogn. Emot.* 16, 355–379. doi: 10.1080/02699930143000527

Fox, E., Russo, R., and Georgiou, G. A. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cogn. Affect. Behav. Neurosci.* 5, 396–404. doi: 10.3758/CABN.5.4.396

Fukuda, K., and Vogel, E. K. (2009). Human variation in overriding attentional capture. *J. Neurosci.* 29, 8726–8733. doi: 10.1523/JNEUROSCI.2145-09.2009

Fukuda, K., and Vogel, E. K. (2011). Individual differences in recovery time from attentional capture. *Psychol. Sci.* 22, 361–368. doi: 10.1177/0956797611398493

Georgiou, G. A., Bleakley, C., Hayward, J., Russo, R., Dutton, K., Eltiti, S., et al. (2005). Focusing on fear: attentional disengagement from emotional faces. *Vis. Cogn.* 12, 145–158. doi: 10.1080/13506280444000076

Koster, E. H. W., Crombez, G., Verschuere, B., Van Damme, S., and Wiersema, J. R. (2006). Components of attentional bias to threat in high trait anxiety: facilitated engagement, impaired disengagement, and attentional avoidance. *Behav. Res. Ther.* 44, 1757–1771. doi: 10.1016/j.brat.2005.12.011

Lamy, D., Leber, A., and Egeth, H. E. (2004). Effects of task relevance and stimulus-driven salience in feature-search mode. *J. Exp. Psychol. Hum. Percept. Perform.* 30, 1019–1031. doi: 10.1037/0096-1523.30.6.1019

Leary, M. R. (1983). A Brief version of the Fear of Negative Evaluation Scale. *Pers. Soc. Psychol. Bull.* 9, 371–375. doi: 10.1177/0146167283093007

Luck, S. J., and Vogel, E. K. (1997). The capacity of visual working memory for features and conjunctions. *Nature* 390, 279–281. doi: 10.1038/36846

McNab, F., and Klingberg, T. (2008). Prefrontal cortex and basal ganglia control access to working memory. *Nat. Neurosci.* 11, 103–107. doi: 10.1038/nn2024

Mogg, K., Philippot, P., and Bradley, B. P. (2004). Selective attention to angry faces in clinical social phobia. *J. Abnorm. Psychol.* 113, 160–165. doi: 10.1037/0021-843X.113.1.160

Moriya, J., and Sugiura, Y. (2012). High visual working memory capacity in trait social anxiety. *PLoS ONE* 7:e34244. doi: 10.1371/journal.pone.0034244

Moriya, J., and Tanno, Y. (2008). Relationships between negative emotionality and attentional control in effortful control. *Pers. Individ. Differ.* 44, 1348–1355. doi: 10.1016/j.paid.2007.12.003

Moriya, J., and Tanno, Y. (2009a). Competition between endogenous and exogenous attention to nonemotional stimuli in social anxiety. *Emotion* 9, 739–743. doi: 10.1037/a0016817

Moriya, J., and Tanno, Y. (2009b). Dysfunction of attentional networks for non-emotional processing in negative affect. *Cogn. Emot.* 23, 1090–1105. doi: 10.1080/02699930802335018

Moriya, J., and Tanno, Y. (2010). Attentional resources in social anxiety and the effects of perceptual load. *Cogn. Emot.* 24, 1329–1348. doi: 10.1080/02699930903378503

Moriya, J., and Tanno, Y. (2011a). Processing of task-irrelevant natural scenes in social anxiety. *Acta Psychol.* 138, 162–170. doi: 10.1016/j.actpsy.2011.05.019

Moriya, J., and Tanno, Y. (2011b). The time course of attentional disengagement from angry faces in social anxiety. *J. Behav. Ther. Exp. Psychiatry* 42, 122–128. doi: 10.1016/j.jbtep.2010.08.001

Moser, J. S., Becker, M. W., and Moran, T. P. (2012). Enhanced attentional capture in trait anxiety. *Emotion* 12, 213–216. doi: 10.1037/a0026156

Peers, P. V., and Lawrence, A. D. (2009). Attentional control of emotional distraction in rapid serial visual presentation. *Emotion* 9, 140–145. doi: 10.1037/a0014507

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: transforming numbers into movies. *Spat. Vis.* 10, 437–442. doi: 10.1163/156856897X00366

Preacher, K., Curran, P., and Bauer, D. (2006). Computational tools for probing interactions in multiple linear regression, multilevel modeling, and latent curve analysis. *J. Educ. Behav. Stat.* 31, 437–448. doi: 10.3102/10769986031004437

Reinholdt-Dunne, M. L., Mogg, K., and Bradley, B. P. (2009). Effects of anxiety and attention control on processing pictorial and linguistic emotional information. *Behav. Res. Ther.* 47, 410–417. doi: 10.1016/j.brat.2009.01.012

Sadeh, N., and Bredemeier, K. (2011). Individual differences at high perceptual load: the relation between trait anxiety and selective attention. *Cogn. Emot.* 25, 747–755. doi: 10.1080/02699931.2010.500566

Sasagawa, S., Yoshihiro, K., Yasuko, M., Suzuki, S., Shimada, H., and Sakano, Y. (2004). Development of a short fear of negative evaluation scale for Japanese using item response theory. *Jpn. J. Behav. Ther.* 30, 87–98.

Schmidt, N. B., Richey, J. A., Buckner, J. D., and Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *J. Abnorm. Psychol.* 118, 5–14. doi: 10.1037/a0013643

Susa, G., Pitică, I., Benga, O., and Miclea, M. (2012). The self regulatory effect of attentional control in modulating the relationship between attentional biases toward threat and anxiety symptoms in children. *Cogn. Emot.* 26, 1069–1083. doi: 10.1080/02699931.2011.638910

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Percept. Psychophys.* 51, 599–606. doi: 10.3758/BF03211656

Visu-Petra, L., Cheie, L., Benga, O., and Packiam Alloway, T. (2011). Effects of anxiety on memory storage and updating in young children. *Int. J. Behav. Dev.* 35, 38–47. doi: 10.1177/0165025410368945

Vogel, E. K., and Machizawa, M. G. (2004). Neural activity predicts individual differences in visual working memory capacity. *Nature* 428, 748–751. doi: 10.1038/nature02447

Vogel, E. K., McCollough, A. W., and Machizawa, M. G. (2005). Neural measures reveal individual differences in controlling access to working memory. *Nature* 438, 500–503. doi: 10.1038/nature04171

Vogt, J., De Houwer, J., Crombez, G., and Van Damme, S. (2013). Competing for attentional priority: temporary goals versus threats. *Emotion* 13, 587–598. doi: 10.1037/a0027204

Wieser, M. J., McTeague, L. M., and Keil, A. (2012). Competition effects of threatening faces in social anxiety. *Emotion* 12, 1050–1060. doi: 10.1037/a0027069

Yiend, J., and Mathews, A. (2001). Anxiety and attention to threatening pictures. *Q. J. Exp. Psychol.* 54A, 665–681. doi: 10.1080/713755991

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Indicators of implicit and explicit social anxiety influence threat-related interpretive bias as a function of working memory capacity

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Interpretive biases play a crucial role in anxiety disorders. The aim of the current study was to examine factors that determine the relative strength of threat-related interpretive biases that are characteristic of individuals high in social anxiety. Different (dual process) models argue that both implicit and explicit processes determine information processing biases and behavior, and that their impact is moderated by the availability of executive resources such as working memory capacity (WMC). Based on these models, we expected indicators of implicit social anxiety to predict threat-related interpretive bias in individuals low, but not high in WMC. Indicators of explicit social anxiety should predict threat-related interpretive bias in individuals high, but not low in WMC. As expected, WMC moderated the impact of implicit social anxiety on threat-related interpretive bias, although the simple slope for individuals low in WMC was not statistically significant. The hypotheses regarding explicit social anxiety (with fear of negative evaluation used as an indicator) were fully supported. The clinical implications of these findings are discussed.

Keywords: threat-related interpretive bias, dual process model, working memory capacity, anxiety

INTRODUCTION

Sarah is talking to someone and that person suddenly starts to yawn. She immediately thinks that she is telling a boring story and that she is a dead loss as a storyteller. Negatively biased interpretations of ambiguous social events such as this one by Sarah are known to be characteristic of individuals high in social anxiety (Mathews and Mackintosh, 1998). It has been argued that both for theoretical and clinical reasons, it is important to understand the mechanisms underlying this threat-related interpretive bias (Blanchette and Richards, 2010). Therefore, the aim of the current study was to examine the role of both explicit and implicit anxiety, and regulatory control processes in relation to this threat-related interpretive bias.

Dual process models propose that behavioral responses are the consequence of two different types of processes; implicit and explicit processes (e.g., Strack and Deutsch, 2004). These models have recently been applied to psychopathology (anxiety: Ouimet et al., 2009; depression: Beevers, 2005). While specific descriptions vary, it has been argued that implicit processes are based on automatic associations of concepts in memory and more explicit processes are characterized by more propositional knowledge. Importantly, it is assumed that the relative impact of these processes depends on the availability of control resources, for example dispositional factors such as working memory capacity (WMC, Hofmann et al., 2008). The behavior of individuals high in WMC is expected to be more strongly influenced by explicit processes, while behavior of individuals low in WMC is expected to be more strongly influenced by implicit processes. These assumptions have been supported for self-regulatory behaviors in domains such as aggression, food consumption, and sexual interest behavior (Hofmann et al., 2008). For example, automatic attitudes on eating predicted actual candy eating in participants with low WMC, but not in participants with high WMC. The opposite pattern was observed for more explicit attitudes on eating; this predicted the amount of candy consumed only in individuals with high WMC (Hofmann et al., 2008).

Specific models in the field of anxiety argue that processing biases can also be conceptualized as the joint outcome of an interaction between automatic tendencies and control over these tendencies. Mathews and Mackintosh (1998), for example, proposed a model in which threat-related biases in information processing depend on activation of a more automatic threat-detection system and a top-down regulatory control system. Biases in information processing are predicted to be present when the activation of the affective system exceeds the capacity for control over (mental) contents (see also Mathews and MacLeod, 2005). Neurobiological data suggest that threat-related information processing might be related to increased amygdala activity coupled with a decrease in the recruitment of prefrontal control mechanisms (Blanchette and Richards, 2010). Derryberry and Reed (2002) provided empirical support for such claims regarding threat-related attentional bias; anxious individuals with low levels of regulatory control had stronger threat-related attentional biases than anxious individuals with high levels of regulatory control (comparable findings have been observed for alcohol-related attentional bias; Friese et al., 2010). Less is known regarding such an interaction in threat-related interpretive bias.

The aim of the current study is to examine whether the expression of threat-related interpretive bias would arise from a similar interaction between anxiety and regulatory control. While threat-related interpretive biases have been studied for decades, little research has investigated the psychological processes that determine the strength of such biases. We plan to fill this gap by building on the outlined dual-process frameworks. We made a distinction between explicit and implicit indices of social anxiety as research has shown that these indices explain additional variance in anxiety and are differentially related to aspects of anxiety-related (psychopathological) behavior (Egloff and Schmukle, 2002; Glashouwer and De Jong, 2010). In a series of studies, Egloff and Schmukle showed that implicit indicators of anxiety (automatic associations of the self with anxiety) and explicit indicators of anxiety (deliberate judgments of the self as anxious) functioned in a complementary manner. For example implicit indicators predicted change in performance after stress that explicit indicators were unable to predict. In the current study, fear of negative evaluation was used as an indicator of explicit social anxiety as it is considered a core feature of social anxiety (Rapee and Heimberg, 1997) and often used in research [for a meta-analysis see Acarturk et al. (2009)]. Dual-process theories propose that implicit processes impact stronger on indices of outcome behavior in individuals with low regulatory control but not high in regulatory control as individuals with high regulatory control are expected to have enough capacity to override the influence of the automatic system. In the current context of anxiety, it has been suggested that "…anxious individuals find attending to threatening stimuli distressing and consequently try to avoid them …" (Mathews and Mackintosh, 1998, p. 546) and individuals with high regulatory control might be better in achieving that. Conversely, it is proposed that explicit processes impact stronger on behavior in individuals with high levels of control. We expected based on dual process models and earlier findings regarding attentional bias, that indicators of implicit social anxiety (Egloff and Schmukle, 2002; Westberg et al., 2007) predict threat-related interpretive bias for individuals low, but not high in WMC. Conversely, indicators of explicit social anxiety predict interpretive bias for individuals high, but not low in WMC. These hypotheses postulate a dynamic interplay of different psychological processes interacting to determine the strength of threat-related interpretive biases. They thereby go beyond the assumption of main effects (i.e., stronger social anxiety leads to a stronger interpretive bias) by distinguishing between the differential influences of implicit and explicit indicators of social anxiety and identifying the boundary conditions when they will be more or less influential in impacting upon interpretive biases. Support for these assumptions would provide novel and unique evidence for the psychological processes underlying the expression of threat-related interpretive biases and how they interact in determining the magnitude of these biases.

METHODS[1]

PARTICIPANTS

A total of 79 participants aged between 18 and 35 years were recruited from the University of East Anglia via posters and online advertisements regarding the effects of emotion on comprehension of information. One participant inadvertently completed the IAT twice and because the first assessment data were overwritten by the second, the data were excluded. Two further participants were excluded due to high error rates on the operation span task. Finally, preparatory regression analyses revealed four multivariate outliers (based on studentized deleted residuals and mahalanobis distance) who were excluded from the analyses. The final sample consisted of 72 participants and the mean age was 23.64 years ($SD = 4.16$, 49 females). Participants were either entered into a prize draw or received £8 to compensate for their time.

MATERIALS

Implicit association test (IAT)

An IAT containing self and social anxiety related words was used as an indicator of implicit social anxiety (Egloff and Schmukle, 2002; Westberg et al., 2007). Participants had to classify stimuli from four categories using two response keys; one categorization concerned *self* vs. *others* and the second concerned *social anxiety* vs. *relaxed*. The IAT consisted of seven blocks. During the first block, participants practiced categorizing stimuli into the *self* or *others* categories (20 trials) and in the second block into the *social anxiety* or *relaxed* categories (20 trials). In the third and fourth block (combination blocks), participants classified stimuli into all categories simultaneously (20 trials and 60 trials, respectively). Participants pressed one key when stimuli referred to either *self* or *social anxiety* and another key when they referred to *others* or *relaxed*. In the fifth block (40 trials), the categories *social anxiety* and *relaxed* changed sides resulting in opposite response assignments. In the sixth and seventh block (reversed combination blocks), participants again categorized all categories simultaneously (20 trials and 60 trials respectively). An IAT-index was calculated using the D600 improved scoring algorithm (Greenwald et al., 2003). Following the formula presented by Greenwald et al., all combination blocks were included (blocks 3, 4, 6, and 7), error penalties (600 ms) were given, and results were standardized at the level of the participant. The D600 measure was calculated so that higher scores reflect stronger associations between "self" and "social anxiety" as compared to "self" and "relaxed." It thus provides a relative measure of the implicit association between self and social anxiety. Previous research has demonstrated that the anxiety IAT exhibits good internal consistency (Cronbach's alphas in the range of 0.80) and predicts behavioral indicators of anxiety (Egloff and Schmukle, 2002).

[1]Only those measures relevant for the current hypotheses are listed here. Participants also completed questionnaires regarding general state and trait anxiety, the IAT stimuli, a lexical decision task and an unvalidated ad-hoc created questionnaire regarding personal goal orientation concerning the handling of social situations in everyday life.

Fear of negative evaluation (FNE)

The FNE scale measures fear of being evaluated negatively by others and was used as an indicator of explicit social anxiety (Watson and Friend, 1969). It comprises 30 statements (e.g., I rarely worry about seeming foolish to others), asking participants to rate each item as either true or false. The FNE has alpha coefficients of 0.94 (student population, Watson and Friend, 1969; clinical population, Oei et al., 1991), indicative of high internal consistency.

Complex operation span task (OSPAN)

The OSPAN is a widely used complex operation span task, providing a measure of individual differences in WMC (Unsworth et al., 2005). Participants were presented with a set of equations on the screen consisting of one addition or subtraction and a multiplication [e.g., $(2 \times 4) - 3 = 5$]. They were asked to indicate whether the presented result was true or false. Then a letter was presented and participants remembered the letters in the order in which they appeared. Feedback was provided regarding the number of correctly solved equations and letters recalled. The program started with a practice phase consisting of practicing letter recall, math portions, and their combination respectively. In the assessment phase, participants received three trials of each set size, with set sizes ranging from three to seven. Order of set sizes was random for each participant. An 85% accuracy criterion on the math operations was required for all the participants to ensure that they were not trading off between solving the operations and remembering the words (Unsworth et al., 2005). A WMC index was computed by summing up the number of correctly recalled sets. This index has both good internal consistency (alpha = 0.78) and test-retest reliability (0.83), and was correlated with other WM span measures and with a factor composed of fluid abilities measures (Unsworth et al., 2005).

Word sentence association paradigm (WSAP)

The WSAP provides an assessment of threat-related interpretive bias (Beard and Amir, 2008, 2009). On each trial, a word was presented for 500 ms, followed by a sentence. For half of the trials, the word and sentence facilitated a threat-related interpretation (e.g., embarrassing—People laugh after something you said), and on the other half a non-threat-related interpretation (e.g., funny—People laugh after something you said). Participants indicated whether the word and sentence were related by pressing a "Yes" or "No" key. Seventy-six sentences describing social situations were selected from those used by Beard and Amir (2008, 2009). Each sentence was once paired with a threat-related and once with a non-threat-related word. These 152 word-sentence pairs were divided into two sets and participants were randomly assigned to a set. An interpretive bias index was calculated by subtracting the percentage of non-threat-related endorsements from the percentage of threat-related endorsements and higher scores represent a stronger threat-related interpretive bias. Previous research has revealed that both threat endorsements and non-threat endorsements were significantly correlated with level of social anxiety (Beard and Amir, 2008, 2009).

PROCEDURE

Participants received an information sheet and provided informed consent. Next, participants completed the IAT, the OSPAN, and the WSAP on the computer before completing the FNE scale using paper and pencil. Finally, participants were debriefed and given the opportunity to ask questions. The testing session lasted approximately 60 min.

RESULTS

To examine the relationship between indicators of implicit and explicit social anxiety, WMC, and threat-related interpretive bias, zero-order correlations were computed between these variables (see **Table 1** for means, standard deviations, and correlations). Explicit social anxiety, as indicated by the FNE scale, was positively associated with threat-related interpretive bias and implicit social anxiety, as indicated by the IAT, correlated positively with WMC. These zero-order correlations should, however, be interpreted in the context of the multiple regression analyses reported next.

In order to investigate whether WMC moderates the impact of implicit and explicit indicators of social anxiety on threat-related interpretive bias, we performed a moderated regression analysis on interpretive bias as the dependent variable. To reduce multicollinearity and to arrive at the correct beta weights, all variables were first z-standardized (Aiken and West, 1991). As predictors, we entered implicit social anxiety (indicated by the IAT), explicit social anxiety (indicated by the FNE scale), WMC, and the interactions between implicit social anxiety and WMC, and explicit social anxiety and WMC[2]. The regression analysis [$R^2 = 0.22$, $F_{(5,\ 71)} = 3.76$, $p = 0.005$] yielded three significant predictors; explicit social anxiety, $\beta = 0.24$, $p = 0.029$, and the predicted interaction effects of implicit social anxiety × WMC, $\beta = -0.24$, $p = 0.048$, and explicit social anxiety × WMC, $\beta = 0.35$, $p = 0.007$. Consistent with previous studies, high scores on

Table 1 | Correlations between indicators of implicit and explicit social anxiety, WMC, and threat-related interpretive bias, (*n* = 72).

	1.	2.	3.	4.
1. Implicit social anxiety (indicated by the IAT)	–			
2. Explicit social anxiety (indicated by the FNE)	−0.05	–		
3. Working memory capacity (indicated by the OSPAN)	0.44**	−0.06	–	
4. Threat-related interpretive bias (indicated by the WSAP)	0.04	0.24*	0.10	–
M	−0.15	16.8	40.7	−20.9
SD	0.31	6.9	14.6	15.4

*Note: *p < 0.05, **p < 0.01. IAT, implicit association test; FNE, fear of negative evaluation scale; OSPAN, complex operation span task; WSAP, word sentence association paradigm.*

[2]To examine the influence of age on the results, we repeated the regression analysis with age added as an additional predictor. Age was not a significant predictor and the previously significant predictors remained significant.

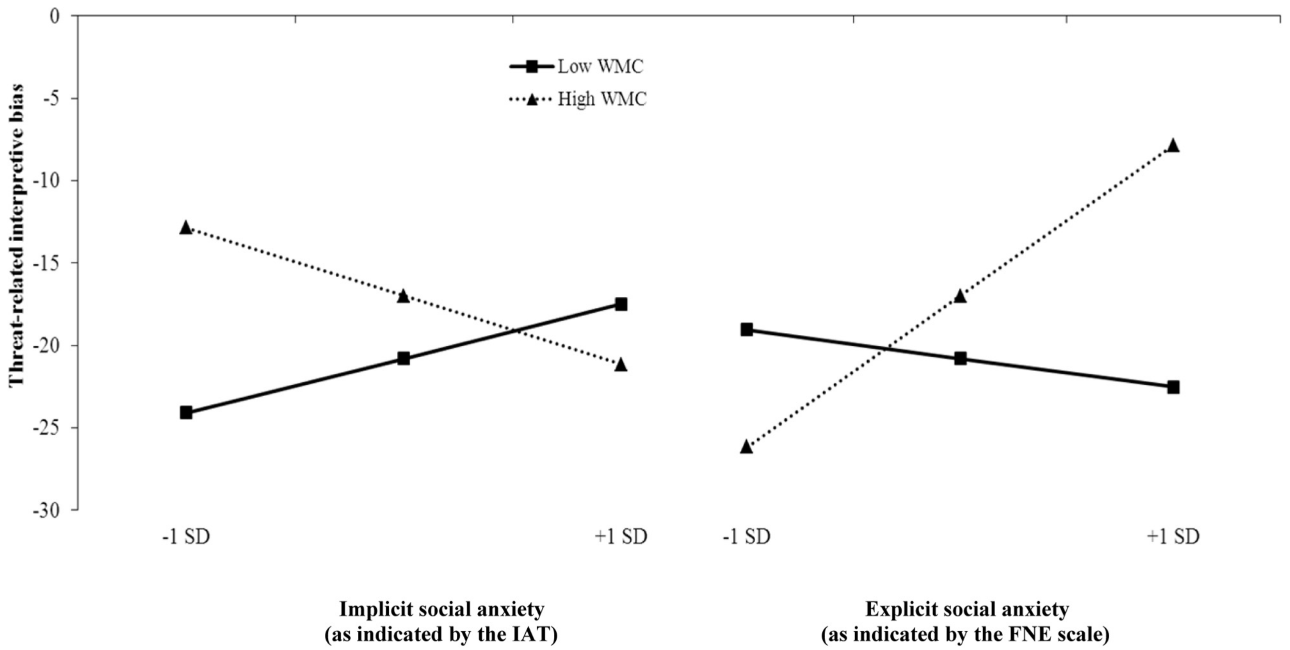

FIGURE 1 | Influence of indicators of implicit and explicit social anxiety on threat-related interpretive bias as a function of working memory capacity (WMC). The graph shows predicted interpretive bias scores (not standardized for illustrative purposes) for individuals with low (−1 SD) and high (+1 SD) implicit social anxiety, as indicated by the IAT, (left panel) or individuals with low (−1 SD) and high (+1 SD) fear of negative evaluation as an indicator of explicit social anxiety (right panel) depending on low (−1 SD) and high (+1 SD) working memory capacity.

fear of negative evaluation (as an indicator of explicit social anxiety) were associated with a stronger threat-related interpretive bias. The interaction effects are depicted in **Figure 1** (left: implicit social anxiety, as indicated by the IAT; right: explicit social anxiety, as indicated by the FNE scale). As expected, the significant interaction between implicit social anxiety and WMC appears to indicate that IAT scores, as an indicator of implicit social anxiety, were positively associated with threat-related interpretive bias for individuals low in WMC, with an opposite pattern of effects for participants high in WMC. However, although the interaction revealed the expected moderating effect of WMC, simple slope analyses were not significant for either those low, $\beta = 0.21$, $p = 0.195$, or high in WMC $\beta = -0.27$, $p = 0.135$. Regarding the explicit social anxiety (as indicated by the FNE scale) × WMC interaction, simple slope tests confirmed the hypothesis that explicit social anxiety as indicated by the FNE scale predicted interpretive bias for individuals high ($\beta = 0.60$, $p < 0.001$), but not low in WMC ($\beta = -0.11$, $p = 0.522$).

DISCUSSION

The present study drew on contemporary dual-process models (Mathews and Mackintosh, 1998; Strack and Deutsch, 2004; Ouimet et al., 2009) to investigate the assumption that the magnitude of threat-related interpretive bias depends on indicators of both implicit and explicit social anxiety and that their relative influences crucially hinge on the availability of control resources such as WMC. As predicted, WMC moderated the impact of the implicit indicator of social anxiety on interpretive bias, with the results suggesting a positive relationship between implicit social anxiety, as indicated by the IAT, and interpretive bias for individuals with low, but not high WMC (though the slope failed to reach significance). The predicted opposite pattern was observed for the indicator of explicit social anxiety; fear of negative evaluation was only associated with threat-related interpretive bias in individuals with high, but not low levels of WMC.

While it has been theoretically argued that threat-related interpretive biases are the joint outcome of two tendencies (Mathews and Mackintosh, 1998), empirical data supporting this claim was lacking. To the best of our knowledge, the present study is the first to provide empirical evidence that threat-related interpretive biases can be conceptualized as the result of an interplay between indicators of implicit and explicit social anxiety on the one hand and WMC on the other hand. More generally, the current findings are consistent with studies in the field of health psychology that revealed that control processes can moderate the impact of implicit and explicit processes on self-regulatory behavior (Hofmann et al., 2008; Friese and Hofmann, 2012) and on biases in information processing (Friese et al., 2010).

The finding regarding the role of implicit social anxiety requires future research as the hypothesized slope in individuals with low WMC was not significant and an unexpected positive correlation between implicit social anxiety and WMC was observed. This might be related to the type of IAT used in the current study. That is, implicit social anxiety was indicated by an social anxiety IAT, which assessed the relative strength of associations between the self and social anxiety. While this measure has been used in other studies examining social anxiety (Egloff and Schmukle, 2002; Westberg et al., 2007), in retrospect, it might have been conceptually different from the processes in social anxiety that we focused on. That is, there seems to be a match in content between the explicit indicator of social anxiety (fear of negative evaluations) and the outcome variable (negative interpretive bias in social situations), while the anxiety IAT seems conceptually different. A social evaluative IAT (see for example Clerkin and Teachman, 2010) might potentially better capture the relevant processes and have a different and potentially stronger impact on threat-related interpretive bias. Additionally, the IAT provides a measure of relative strength of associations and is not an absolute measure. Despite these shortcomings, the IAT revealed the hypothesized interaction with WMC in the prediction of threat-related interpretive bias.

Some other study limitations should be acknowledged. In line with previous research (Acarturk et al., 2009), we used fear of negative evaluation as an indicator of explicit social anxiety. It is important to acknowledge that while fear of negative evaluation is considered a hallmark aspect of social anxiety (Rapee and Heimberg, 1997), both constructs are highly related, but not identical (Weeks et al., 2005). Future research should investigate the generalizability of the present findings by replicating this study using other indicators of explicit social anxiety, for example, the Social Phobia Scale and Social Interaction Anxiety Scale (Mattick and Clarke, 1998) or the Liebowitz Social Anxiety Scale (Liebowitz, 1987). In addition, given the comorbidity between anxiety and depression, it would be important to control for depression in future studies. A more methodological limitation is the task order. All participants completed the tasks in the same order (IAT, OSPAN, WSAP, FNE). While this is consistent with other studies examining moderated predictive validity of implicit measures (Hofmann et al., 2008; Friese et al., 2010; Friese and Hofmann, 2012), we cannot rule out that this order might have influenced the results. For example, the OSPAN could have been perceived as stressful, and potentially especially for anxious individuals, and this might have (differentially) affected subsequent assessments. Also, FNE scores may have been inflated for individuals with higher levels of social anxiety due to priming effects by the IAT and WSAP. Importantly, if existent, such a bias would have had negative effects on the overall validity of the scale and should have made it more unlikely (not more likely) to detect the predicted moderation effect. Finally, we tested the theoretical model in unselected individuals. To investigate the clinical implications of our findings, future studies should test the model in highly-anxious (sub)clinical populations as such individuals are specifically characterized by threat-related biases. In addition, directly comparing clinically and non-clinically anxious individuals would be interesting as it has been suggested that those groups differ in the ability to regulate their information processing biases (Macleod and Rutherford, 1992).

The current findings shed light on the underpinnings of threat-related interpretive bias. They have a range of potentially clinically relevant implications. In addition to recent developments regarding interventions that are designed to directly modify information processing biases (CBM training, Macleod and Mathews, 2012), the current findings reveal potential determinants of threat-related interpretive bias. Changing these determinants might affect information processing, however, as the current study has a correlational design, more research is necessary to examine whether those processes are causal agents. There is promising evidence for each process (implicit processes, explicit processes, and WMC) that changing them might be beneficial. First, it has been shown that implicit associations can be modified using Cognitive Behavior Therapy (CBT, Teachman et al., 2008), but also by performing repeated avoidance responses (Wiers et al., 2011). Second, CBT can also change explicit processes such as self-reported socially anxious feelings (Hofmann et al., 2012). Third, increasing control resources might be beneficial as it would allow an individual to counteract the impact of their implicit processes. Indeed, there are exciting possibilities to directly enhance WMC; either using computerized WM training (Klingberg et al., 2005; but see Owen et al., 2010) or transcranial Direct Current Stimulation (Boggio et al., 2007). Thus, the current study identified three types of processes that were related to interpretive bias and recent findings suggest that each of these processes can be modified and, more importantly, affect symptoms of psychopathology.

In conclusion, individual differences in WMC moderated the association between indicators of both implicit and explicit social anxiety on the one hand, and threat-related interpretive biases on the other hand. These findings have significant theoretical and clinical implications.

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REFERENCES

Acarturk, C., Cuijpers, P., Van Straten, A., and De Graaf, R. (2009). Psychological treatment of social anxiety disorder: a meta-analysis. *Psychol. Med.* 39, 241–254.

Aiken, L. S., and West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. Thousand Oaks, CA: Sage.

Beard, C., and Amir, N. (2008). A multi-session interpretation modification program: changes in interpretation and social anxiety symptoms. *Behav. Res. Ther.* 46, 1135–1141.

Beard, C., and Amir, N. (2009). Interpretation in social anxiety: when meaning precedes ambiguity. *Cogn. Ther. Res.* 33, 406–415.

Beevers, C. G. (2005). Cognitive vulnerability to depression: a dual process model. *Clin. Psychol. Rev.* 25, 975–1002.

Blanchette, I., and Richards, A. (2010). The influence of affect on higher level cognition: a review of research on interpretation, judgement, decision making and reasoning. *Cogn. Emot.* 24, 561–595.

Boggio, P. S., Bermpohl, F., Vergara, A. O., Muniz, A. L., Nahas, F. H., Leme, P. B., et al. (2007). Go-no-go task performance improvement after anodal transcranial DC stimulation of the left dorsolateral prefrontal cortex in major depression. *J. Affect. Disord.* 101, 91–98.

Clerkin, E. M., and Teachman, B. A. (2010). Training implicit social anxiety associations: an experimental intervention. *J. Anxiety Disord.* 24, 300–308.

Derryberry, D., and Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *J. Abnorm. Psychol.* 111, 225–236.

Egloff, B., and Schmukle, S. C. (2002). Predictive validity of an implicit association test for assessing anxiety. *J. Pers. Soc. Psychol.* 83, 1441–1455.

Friese, M., Bargas-Avila, J., Hofmann, W., and Wiers, R. W. (2010). Here's looking at you, bud: alcohol-related memory structures predict eye movements for social drinkers with low executive control. *Soc. Psychol. Pers. Sci.* 1, 143–151.

Friese, M., and Hofmann, W. (2012). Just a little bit longer: viewing time of erotic material from a self-control perspective. *Appl. Cogn. Psychol.* 26, 489–496.

Glashouwer, K., and De Jong, P. (2010). Disorder-specific automatic self-associations in depression and anxiety: results of the Netherlands study of depression and anxiety. *Psychol. Med.* 40, 1101–1111.

Greenwald, A. G., Nosek, B. A., and Banaji, M. R. (2003). Understanding and using the Implicit Association Test: I. An improved scoring algorithm. *J. Pers. Soc. Psychol.* 85, 197–216.

Hofmann, S. G., Asnaani, A., Vonk, I. J. J., Sawyer, A. T., and Fang, A. (2012). The efficacy of Cognitive Behavioral Therapy: a review of meta-analyses. *Cogn. Ther. Res.* 36, 427–440.

Hofmann, W., Gschwendner, T., Friese, M., Wiers, R. W., and Schmitt, M. (2008). Working memory capacity and self-regulatory behavior: toward individual differences perspective on behavior determination by automatic versus controlled processes. *J. Pers. Soc. Psychol.* 95, 962–977.

Klingberg, T., Fernell, E., Olesen, P. J., Johnson, M., Gustafsson, P., Dahlström, K., et al. (2005). Computerized training of working memory in children with ADHD: a randomized, controlled trial. *J. Am. Acad. Child Adolesc. Psychiatry* 44, 177–186.

Liebowitz, M. R. (1987). Social phobia. *Mod. Probl. Pharmacopsychiatry* 22, 141–173.

Macleod, C., and Mathews, A. (2012). Cognitive Bias Modification approaches to anxiety. *Ann. Rev. Clin. Psychol.* 8, 189–217.

Macleod, C., and Rutherford, E. M. (1992). Anxiety and the selective processing of emotional information: mediating roles of awareness, trait and state variables, and personal relevance of the stimulus materials. *Behav. Res. Ther.* 30, 479–491.

Mathews, A., and Mackintosh, B. (1998). A cognitive model of selective processing in anxiety. *Cogn. Ther. Res.* 22, 539–560.

Mathews, A., and MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annu. Rev. Clin. Psychol.* 1, 167–195.

Mattick, R. P., and Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav. Res. Ther.* 36, 455–470.

Oei, T. P. S., Kenna, D., and Evans, L. (1991). The reliability, validity and utility of the SAD and FNE scales for anxiety disorder patients. *Pers. Individ. Dif.* 12, 111–116.

Ouimet, A. J., Gawronski, B., and Dozois, D. J. A. (2009). Cognitive vulnerability to anxiety: a review and an integrative model. *Clin. Psychol. Rev.* 29, 459–470.

Owen, A. M., Hampshire, A., Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., et al. (2010). Putting brain training to the test. *Nature* 465, 775–778.

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756.

Strack, F., and Deutsch, R. (2004). Reflective and impulsive determinants of social behaviour. *Pers. Soc. Psychol. Rev.* 8, 220–247.

Teachman, B. A., Marker, C. D., and Smith-Janik, S. B. (2008). Automatic associations and panic disorder: trajectories of change over the course of treatment. *J. Consult. Clin. Psychol.* 76, 988–1002.

Unsworth, N., Heitz, R. P., Schrock, J. C., and Engle, R. W. (2005). An automated version of the operation span task. *Behav. Res. Methods* 37, 498–505.

Watson, D., and Friend, R. (1969). Measurement of social-evaluative anxiety. *J. Consult. Clin. Psychol.* 33, 448–457.

Weeks, J. W., Heimberg, R. G., Fresco, D. M., Hart, T. A., Turk, C. L., Schneier, F. R., et al. (2005). Empirical validation and psychometric evaluation of the brief fear of negative evaluation scale in patients with social anxiety disorder. *Psychol. Assess.* 17, 179–190.

Westberg, P., Lundh, L., and Jönsson, P. (2007). Implicit associations and social anxiety. *Cogn. Behav. Ther.* 36, 43–51.

Wiers, R. W., Eberl, C., Rinck, M., Becker, E. S., and Lindenmeyer, J. (2011). Retraining automatic action tendencies changes alcoholic patients' approach bias for alcohol and improves treatment outcome. *Psychol. Sci.* 22, 490–497.

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More than a face: a unified theoretical perspective on nonverbal social cue processing in social anxiety

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Processing of nonverbal social cues (NVSCs) is essential to interpersonal functioning and is particularly relevant to models of social anxiety. This article provides a review of the literature on NVSC processing from the perspective of social rank and affiliation biobehavioral systems (ABSs), based on functional analysis of human sociality. We examine the potential of this framework for integrating cognitive, interpersonal, and evolutionary accounts of social anxiety. We argue that NVSCs are uniquely suited to rapid and effective conveyance of emotional, motivational, and trait information and that various channels are differentially effective in transmitting such information. First, we review studies on perception of NVSCs through face, voice, and body. We begin with studies that utilized information processing or imaging paradigms to assess NVSC perception. This research demonstrated that social anxiety is associated with biased attention to, and interpretation of, emotional facial expressions (EFEs) and emotional prosody. Findings regarding body and posture remain scarce. Next, we review studies on NVSC expression, which pinpointed links between social anxiety and disturbances in eye gaze, facial expressivity, and vocal properties of spontaneous and planned speech. Again, links between social anxiety and posture were understudied. Although cognitive, interpersonal, and evolutionary theories have described different pathways to social anxiety, all three models focus on interrelations among cognition, subjective experience, and social behavior. NVSC processing and production comprise the juncture where these theories intersect. In light of the conceptualizations emerging from the review, we highlight several directions for future research including focus on NVSCs as indexing reactions to changes in belongingness and social rank, the moderating role of gender, and the therapeutic opportunities offered by embodied cognition to treat social anxiety.

Keywords: social anxiety, non-verbal behavior, social rank, dominance, affiliation, production, expression

INTRODUCTION

Individuals with social anxiety disorder (SAD) suffer from significant functional impairment in multiple aspects of daily life: Their academic trajectory is frequently interrupted, they are employed below potential, and their social functioning suffers (Stein and Kean, 2000; Eng et al., 2005; Aderka et al., 2012). Individuals who are high in social anxiety perceive themselves as submissive and behave in nonassertive ways (Aderka et al., 2009; Schneier et al., 2009; Weeks et al., 2011). Moreover, social anxiety has been associated with lower reported quality of intimacy in peer, friendship, and romantic relationships (Rodebaugh, 2009; Cuming and Rapee, 2010; Weisman et al., 2011). Detailed analyzes of interpersonal behavior suggested that individuals with high social anxiety appear less confident, less affiliative, and less synchronous in social interactions than individuals with low social anxiety (e.g., Fydrich et al., 1998; Kachin et al., 2001; Alden and Taylor, 2004).

In this article we examine difficulties in interpersonal communication in social anxiety from the perspective of functional analysis of human sociality (e.g., Bugental, 2000). From this perspective, each individual participates in several evolutionarily shaped social structures. The two most prominent structures are affiliative relationships (friendship, companionship, intimacy) and hierarchical relationships (authority, social rank, social power). The need to affiliate with or belong to a social group is considered one of the central social motives across species, and basic psychological systems are hypothesized to constantly monitor for inclusionary status (e.g., Baumeister and Leary, 1995). Similarly, a need to advance in the social hierarchy and to be sensitive to threats to one's status within a group appears to be inherited from our primate ancestors (Sapolsky, 2005). Social exclusion (i.e., ostracism or social rejection) and social submission (e.g., being defeated) threaten one's belonging to and standing in a social group. Such events also decrease one's chances of future social effectiveness and collaboration. In contrast, social acceptance and social ascendance increase one's chances of social flourishing. In the following, we review some evidence that social rank and affiliation are basic psychological systems and then we examine their links with nonverbal social cue (NVSC).

SOCIAL RANK BIOBEHAVIORAL SYSTEM (SRBS)

A distinctive feature of social species' cooperative living is the formation of dominance hierarchies (e.g., Rowell, 1974). Conspecific members of the species face competition for resources, leading to aggressive interactions (West-Eberhard, 1979). Social hierarchies afford dominant members privileged access to food and mates, thereby conferring survival advantages. Such hierarchies are social systems containing an "implicit or explicit rank order of individuals or groups with respect to a valued social dimension" (Magee and Galinsky, 2008, p. 354). Social hierarchies contribute to stable social organization, and this stability reduces the costs of social competition for both dominant and subordinate members (e.g., Sloman and Armstrong, 2002). Possibly due to its importance for survival, a specialized biobehavioral system that monitors for social rank appears to have developed in humans and other mammals. This biobehavioral system has been called the rank regulation system (Zuroff et al., 2010), hierarchical domain (Bugental, 2000), power (Shaver et al., 2011), or dominance behavior system (Johnson et al., 2012).

The Social rank biobehavioral system (SRBS) is postulated as constantly monitoring one's standing in relation to others and using that information to guide behavior (e.g., Silk, 2007). Neuroimaging evidence supported the role of limbic, prefrontal, and striatal pathways (Beasley et al., 2012) and possibly intraparietal sulci (Chiao et al., 2009) in human social rank processing. Moreover, individual differences in social rank were linked to neural activation of limbic and frontal pathways when viewing social information (e.g., Muscatell et al., 2012). The most frequently studied SRBS-related biochemical substrate has been testosterone (e.g., Schultheiss and Wirth, 2008). Testosterone was found to correlate with self-report, observational, and cognitive measures of dominance in men and women alike (e.g., Archer, 2006; Sellers et al., 2007); additionally, estradiol correlated with dominance in females (e.g., Stanton and Schultheiss, 2007).

SRBS appears to emerge early in the developmental sequence (Thomsen et al., 2011), to operate automatically (Moors and De Houwer, 2005; Tracy et al., 2013) and fluently (Zitek and Tiedens, 2012), and to be specifically attuned to certain nonverbal signals such as gaze, voice, gestures, and postures (Wolff and Puts, 2010; Terburg et al., 2012; Tracy et al., 2013). Thus, SRBS is postulated to organize and orchestrate individuals' responses to changes in social standing.

AFFILIATION BIOBEHAVIORAL SYSTEM (ABS)

Over the course of human evolutionary history, members of the same species depended on each other for survival. In humans and other mammals, individuals who could gather support from their social surroundings gained access to more resources and therefore increased their chances of survival and reproduction. Like the dominance system, affiliative system is another basic biobehavioral system which continuously monitors for inclusionary status (Baumeister and Leary, 1995). Indeed, failing to satisfy the need to belong was found to activate neural circuits that partially overlap those of physical pain (e.g., Eisenberger et al., 2003; Dewall et al., 2010). Specifically, social exclusion was associated with greater activity in dorsal anterior cingulate cortex (dACC) and anterior insula. Again, individual differences in sensitivity to social exclusion (such as rejection sensitivity and attachment anxiety) were associated with greater responses in these regions (Linnen et al., 2012). Oxytocin and vassopressin, neuropeptides germane to affiliative behavior, may be implicated in the regulation of interpersonal stress (Taylor et al., 2000) and as affecting prosocial behavior (Poulin et al., 2012). Relatedly, intranasal administration of oxytocin reduced distress following social rejection in women who endorsed emotional coping strategies (Cardoso et al., 2012). Moreover, oxytocin administration increased prosocial behavior in women with a history of positive parenting (Riem et al., 2013). ABS emerges early in the developmental sequence (Feldman, 2012), operates automatically (Lakin et al., 2008), and is attuned to nonverbal signals of touch, gaze, and vocalization (Guastella et al., 2008; Dunbar and Abra, 2010; Farley et al., 2013).

Some convergence exists at the conceptual level between the close social bonds system and the belongingness system. In general, the jury is still out whether these two systems are best conceptualized as distinct (e.g., Panksepp and Watt, 2011), or form a single coherent unit (e.g., Feldman, 2012). For purposes of this review we focus on their similarities and view them as one. Thus, we see the ABS as organizing and orchestrating individuals' responses to opportunities to, and ruptures in, social bonds.

SOCIAL RANK, AFFILIATION, AND NONVERBAL SOCIAL CUES (NVSCs)

Consistent evidence showed that social rank is more frequently expressed through nonverbal than verbal cues (e.g., Argyle et al., 1970; Mehrabian, 1970; Mignault and Chaudhuri, 2003). Moreover, when both verbal and nonverbal cues of social rank were present, nonverbal cues were more likely to influence observers' judgments than verbal ones (e.g., Argyle et al., 1970; Jacob et al., 2012). Similarly, affection is also frequently expressed via nonverbal cues such as touch, vocalization, and gaze (e.g., Feldman and Eidelman, 2007; App et al., 2012; Farley et al., 2013). Indeed, people communicate emotions through multiple nonverbal channels such as face, body, voice, and touch (e.g., Buck, 1984).

Communication efficacy has been shown to vary across nonverbal channels in accruing information about likability, dominance, and trustworthiness (e.g., Zuckerman and Driver, 1989; Hall et al., 2005; Todorov et al., 2009, 2013). Researchers posited that information encoded in postures and voices is transmitted more effectively to larger audiences across longer distances, such as to one's social group or across social groups, whereas information encoded in face and touch is more effectively transmitted to proximate others (Tracy and Robins, 2004; App et al., 2012). Correspondingly, social status emotions (such as pride or shame) were shown to be communicated more effectively through the body than through face or touch (App et al., 2012). Moreover, vocal information was found to effectively communicate dominance (Wolff and Puts, 2010), and research on animal and human behavior alike has documented strong links between expansive body postures and trait and state dominance (Weisfeld and Beresford, 1982; Ellyson and Steve, 1985; Hall et al., 2005). Indeed, Stanton et al. (2010) have postulated that the meaning of nonverbal signals as motivated and rewarding for the sender and the perceiver, respectively. Altogether, different lines of research converge in suggesting that: (a) NVSCs are uniquely suited to rapid, effective transmission of emotional, motivational, and trait information and (b) various channels differ in their effectiveness for transmitting this information.

SOCIAL ANXIETY AND NONVERBAL SOCIAL CUES (NVSCs)

To date, the main nonverbal signal examined in the social anxiety context was emotional facial expression (EFE; see Staugaard, 2010 for reviews). There are sound theoretical reasons to focus on EFEs. First, facial affect is instrumental in social development, emotion regulation, and social functioning (e.g., Leppänen and Hietanen, 2001). Second, facial affect is processed by specialized networks within a particular circuit of brain structures, some of which function abnormally in social anxiety (Nakao et al., 2011). Third, as argued by Bistricky et al. (2011), direct gaze can initiate automatic self-referent processing and self-relative-to-other processing (e.g., "Is his response to me unfavorable?"), and these processes are known to be problematic in social anxiety. Fourth, facial affect represents particularly salient information in close interpersonal situations (App et al., 2012).

Other NVSCs share several important characteristics with EFEs. First, NVSCs are mostly involuntary. As a result, they are more likely to serve as "honest signals" of individuals' internal emotions or attitudes toward an interaction partner than more strategically controlled verbal content. Correspondingly, social information processing should be better attuned to NVSCs than to verbally communicated interpersonal information (e.g., Gotlib et al., 2004). Thus, NVSCs may offer more "privileged" access to individuals' formation of approach and avoidance tendencies than would verbal expressions. Second, inasmuch as emotions are preparatory states for action, perceiving NVSCs should prime an immediate social reaction (Frijda, 1986). Indeed, some suggested that NVSCs may constitute a more evocative medium of transmitting emotions than verbal information (Buck and Vanlear, 2002). Third, given the primacy of NVSCs in the developmental sequence, they likely form the foundation for affective sensitivity and regulation (Cozolino, 2002). The preverbal foundation of implicit affective memories has been assumed to form a lasting basis for self and other schemas (e.g., Bistricky et al., 2011).

Although examinations of EFE processing have extended and deepened understanding of social anxiety's basic processes and biases, much may be learned from expanding the framework in two ways. First, the inclusion of new signals and modalities—especially posture and voice—may elucidate how socially anxious individuals process interpersonal information and engage in impression formation and revision. In the following, we seek to summarize the rather disperse literature on NVSC processing in social anxiety, supplementing it with the burgeoning literature on voice and posture processing among nonclinical populations.

Second, we seek to expand the established framework by highlighting the important yet relatively understudied area of NVSC expression. Thus far, the vast majority of studies have examined biases in perception of NVSCs. However, the expression (or production) of those cues is central to interpersonal behavior and may provide an unbiased measure of the expresser's emotional states and interpersonal tendencies and abilities. Moreover, expression of these cues may, in itself, affect the expresser's cognitive and emotional states, thereby attenuating or intensifying those states (e.g., Carney et al., 2010). Consequently, we will review literature on facial, vocal, and postural expression in social anxiety and nonclinical populations.

ORGANIZATION OF THE REVIEW

This review has three broad goals. First, we aim to systematically review empirical studies examining NVSC perception in social anxiety. We focus mostly on research that employed information-processing approaches while incorporating pertinent cognitive neuroscience findings. Specifically, we review findings on perception of faces (including gaze orientation), voices, and bodies (postures and gestures). Second, we aim to review literature on NVSC production. Here we concentrate on mimicry of facial expression, eye gaze, vocal productions, and adoption of posture and body movements. Due to the paucity of research on some of these topics, we will draw on research with normal populations. Third, we aim to integrate these findings with the three prominent theories of social anxiety, and to formulate new testable hypotheses that may contribute to better understanding of this condition's basic underlying mechanisms.

PERCEPTION OF NONVERBAL SOCIAL CUES (NVSCs)

Theoretical accounts converge in suggesting that misinterpretations of neutral or affiliative social signals as threatening are likely to deepen distress and contribute to the maintenance of SAD (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997; Gilbert, 2001; Alden and Taylor, 2004; Hofmann et al., 2004). Consequently, enhanced understanding of factors that influence biased or inaccurate interpretations of NVSC signals may help formulate a more complete, accurate model of SAD. We review available evidence of biases in processing of cues from faces, voices, and bodies. For each channel, we first review the perception of emotional stimuli (i.e., emotional facial expression, prosody, emotional gestures), followed by a review of impression formation from stable cues (e.g., facial features, basic vocal and body characteristics) and integrated nonverbal representations.

FACES

Emotion facial expression (EFE)

We first review studies focusing on EFEs with direct gaze and then studies involving variations in gaze direction.

Attention. In a comprehensive review, Staugaard (2010) concluded that biased processing of threatening vs. neutral or smiling EFEs tended to emerge mostly under conditions of brief exposure and to disappear when exposure time increased. Staugaard's review, which included mostly studies of EFE processing in non-stressful conditions, yielded only elusive differences between individuals with high vs. low social anxiety in attentional processing of threatening EFEs. Overall, eye-tracking studies found that social anxiety tends to correlate with biased attention to threatening as well as smiling EFEs. In fact, several studies found that socially anxious individuals exhibited reduced total fixation time to all emotional stimuli (e.g., Chen et al., 2012). Moreover, although highly socially anxious individuals revealed difficulty disengaging from threatening faces (e.g., Buckner et al., 2010; Moriya and Tanno, 2011; Schofield et al., 2012), they also exhibited slower attentional disengagement from smiling, as compared to neutral, faces (Gilboa-Schechtman et al., 1999). However, using a continuous flickering paradigm, Wieser et al. (2011) found that angry compared to smiling and neutral expressions were associated with greater electrocortical facilitation over visual areas in individuals with high social anxiety, but not in those with low social anxiety.

Kolassa and Miltner (2006) found that angry expressions during an emotion identification task elicited enhanced right temporoparietal N170 in individuals with SAD (Kolassa and Miltner, 2006) and in subclinically socially anxious individuals (Mühlberger et al., 2009). The research team also reported generally enhanced P100 amplitudes both in individuals with SAD and with other anxiety disorders (Kolassa et al., 2007). However, amplitudes of the N170 component and later event related potentials (ERP) components did not differ between SAD, spider phobic, and control participants when schematic emotional faces were presented (Kolassa et al., 2007) or with morphed expressions (Kolassa et al., 2009). Recently, Peschard et al. (2013) identified an enhanced P1 component in processing emotional and neutral faces in social anxiety. Combined, these data suggest that social anxiety may be related to a specific temporal pattern in processing naturalistic facial expressions.

Using fMRI, several studies employing block-designs found enhanced amygdala reactivity to angry faces (Stein, 2002; Straube et al., 2005; Phan et al., 2006; Evans et al., 2008), neutral faces (Birbaumer et al., 1998; Veit et al., 2002), and happy faces (Straube et al., 2005), pointing to hyperactivation of this area in social anxiety for all emotional expressions. Furthermore, researchers suggested that amygdala activation in highly socially anxious individuals may depend more on EFE intensity than on the particular emotion expressed (Yoon et al., 2007).

Altogether, these studies suggest that individuals high in social anxiety exhibit enhanced processing of all facial expressions in some tasks, disengagement difficulties from both threatening and smiling expression (as compared to neutral expressions) on other tasks, and enhanced vigilance/reactivity to angry expression on select tasks.

Interpretation and evaluation. Many studies found no association between social anxiety and labeling accuracy in emotional labeling tasks, especially when participants had unlimited time for completion (e.g., Joormann and Gotlib, 2006; Arrais et al., 2010; Campbell et al., 2009; Heuer et al., 2010). Similarly, several rating studies did not identify differences between individuals with high vs. low social anxiety in evaluating single discrete EFEs (Stein et al., 2002) or mixed displays of smiling, neutral, and angry expressions (Gilboa-Schechtman et al., 2005; Lange et al., 2011). Other studies that examined response latencies to morphed or degraded presentations of emotional expressions typically showed that social anxiety correlated with a lower threshold for identifying angry expressions (e.g., Joormann and Gotlib, 2006; Gilboa-Schechtman et al., 2008). Recently, Arrais et al. (2010) reported that, compared to women low in social anxiety, women high in social anxiety (but not men) required less emotional information to identify smiling, sad, and fearful expressions. Interestingly, when time constraints were introduced in labeling studies, biased interpretation/evaluation of EFEs emerged (e.g., Heuer et al., 2010). In addition, Heuer et al. (2007) found that, as compared to low socially anxious individuals, high socially anxious individuals showed stronger avoidance tendencies of smiling and angry faces, while no such differences with respect to neutral faces were identified. Combined, these studies suggest that persons with high social anxiety tend to exhibit more negative evaluations of ambiguous or smiling EFEs, either on implicit evaluation tasks, or under conditions of high task difficulty. Additionally, when rating studies required participants to engage in impression formation or in predicting emotional impact of possible interactions, persons with high social anxiety rated smiling faces as less approachable and angry faces as more costly (e.g., Campbell et al., 2009; Douilliez et al., 2012).

Memory. The social anxiety literature is mixed regarding memory biases for experimentally presented stimuli. Some studies documented enhanced processing of threatening stimuli (e.g., Foa et al., 2000), whereas others found no such biases (e.g., Rapee et al., 1994; Coles and Heimberg, 2002; Rinck and Becker, 2005 for reviews). Other studies supported the erosion of positive memory biases in SAD (Liang et al., 2011). In general, however, the support is rather modest for negative memory bias or diminished positive bias in SAD using EFEs.

Gaze direction

Eye gaze plays an essential role in social interactions, as averted gaze may relay various social intentions such as submission (Mazur and Booth, 1998), disinterest (Itier and Batty, 2009), or even rejection (e.g., Wirth et al., 2010). Generally, direct gaze (vs. averted) was linked with observers' higher levels of physiological arousal (i.e., skin conductance), an effect enhanced for smiling faces (Pönkänen and Hietanen, 2012). In another study, participants rated averted gaze as less pleasant than direct gaze (Schmitz et al., 2012). In a virtual reality study, women high in social anxiety exhibited greater increase in avoidance while responding to male avatars when avatars had direct gaze than averted gaze while women with low social anxiety did not exhibit this pattern (Wieser et al., 2010). Similarly, high but not low social anxiety in women was linked with greater heart rate acceleration in response to direct, as compared to averted gaze (Wieser et al., 2009). Highly socially anxious individuals demonstrated avoidance of angry facial expressions but only when gaze was direct (vs. averted); however, they exhibited avoidance of smiling expressions regardless of gaze direction (Roelofs et al., 2010). Furthermore, an fMRI study confirmed preferential activation of brain areas related to fear response when SAD patients viewed direct gaze vs. averted gaze (Schneier et al., 2009).

It appears that sensitivity to EFEs may be modulated by gaze direction. Overall, direct (rather than averted) gaze results in higher physiological and neurological responsiveness as well as more pronounced avoidance among individuals high on social anxiety than those low in social anxiety. This sensitivity appears to be accentuated by emotional expressions; yet, more studies are needed to understand the nature of expression-gaze interaction. For example, depending on the emotional expression, direct gaze may suggest aggressive/dominant intent (when paired with angry or even neutral facial expressions) or affiliative intent (when paired with smiling).

To summarize, the EFE literature suggests that in no-stress conditions social anxiety is associated with generalized reactivity to emotional and neutral faces alike. In addition, in some but not all tasks, social anxiety is associated with selective processing of threatening EFEs, and this bias appears to be modulated by the direction of the targets' gaze. Moreover, smiling facial expressions sometimes elicit reactions similar to those elicited by threatening EFEs. The latter finding highlights the complexity of examining facial expressions because they might simultaneously connote dominance and affiliation (Knutson, 1996). Thus, smiles could be negatively interpreted as threatening by virtue of their association with dominance. Alternatively, affiliative signals may invoke expectations of reciprocity, triggering self-evaluative concerns, which in turn can lead to fear and avoidance. The literature may benefit from better understanding how EFE processing is affected by contextual variations (such as gaze, head tilt, or gender) as well as by the perceiver's motivational states.

VOICE

Vocal information is an important channel for assessing an interaction partner's emotional states, intentions, and trait predispositions (Scherer, 1981; Siegman, 1987). Voices are processed early (e.g., Sauter and Eimer, 2010) and automatically (Donohue et al., 2012). Given the importance of vocal communication to the interpretation of social messages, it is surprising that only a handful of studies examined biased processing of vocal information in social anxiety. Existing studies involving social anxiety focus on labeling of, and brain responses to, emotional prosody of various utterances.

In the first study of its kind, Quadflieg et al. (2007) asked individuals with SAD and control participants to label the emotions of pseudo-words pronounced in angry, sad, happy, fearful, disgusted, or neutral tones by male and female actors. Compared to controls, individuals with SAD were more likely to label utterances as fearful or sad. Importantly, like in the evaluation of facial expressions, no group differences emerged regarding valence and arousal ratings for any of the emotional utterances.

In a follow-up study, individuals with SAD and matched controls labeled the emotion or gender of words pronounced with angry or neutral prosody by male and female actors during fMRI scanning (Quadflieg et al., 2008). Angry prosody elicited stronger brain activation than neutral prosody in limbic (insula, amygdala) as well as cortical areas for all participants. Importantly, compared to controls, individuals with SAD had increased activation in the right orbitofrontal cortex in response to angry vs. neutral voices under both task conditions. These results again substantiate findings for EFEs. McClure and Nowicki (2001) examined interpretation of EFE and vocal prosody in children who were high or low on social anxiety. Social anxiety was significantly associated with greater confusion in emotional labeling of vocal cues, where the high anxiety group was more likely than their less anxious peers to confuse other children's sad and fearful voices.

Taken together, the study of vocal prosody suggests that social anxiety appears to affect the interpretation of prosody characteristics. However, to the best of our knowledge, no studies to date examined attention to, or memory for, prosodic information. Moreover, biases in interpreting affectionate prosody remain to be explored.

BODY AND POSTURE

In the last decade, research on facial and vocal displays of emotions has been augmented by the study of postural expressions (e.g., Tracy and Robins, 2004; App et al., 2011; Dael et al., 2012). Indeed, posture appears particularly important for portraying and recognizing affective states. Posture and associated body language serve as a rich source of information for revealing others' goals, intentions, and emotions. These signals are visible and interpretable from a distance, do not require close contact, and allow simultaneous transmission of information to multiple individuals (e.g., Reed et al., 2003, 2006). The ability to engage in configural body processing seems to develop as early as 3 months of age (Gliga and Dehaene-Lambertz, 2005). Fearful, angry, and happy postures can be processed without visual awareness (Stienen and de Gelder, 2011). In addition, postures also transmit signals pertaining to individuals' social rank or status (e.g., Shariff and Tracy, 2009). For example, pride is cross-culturally recognized and easily distinguished from other similar emotions (e.g., happiness; Tracy and Robins, 2007). Recently, Rule et al. (2012) found that perceivers' judgments of posture dominance were significantly more accurate than chance guessing for exposures as brief as 40 ms, with no significant increase in accuracy given additional viewing time.

Few studies have examined processing of postural or any bodily information in social anxiety. Pitterman and Nowicki (2004) found that adults' correct labeling of standing postures (depicting happiness, fear, anger, and sadness) correlated negatively with fear of negative evaluation. In addition, compared to children with attention disorders, children high in social anxiety made more errors identifying angry posture in adult posers (Walker et al., 2011). De Gelder and her colleagues examined how negative affectivity and social inhibition associate with the processing of threatening body expressions (fear and anger; Kret et al., 2011). They found that negative affectivity correlated with deactivation of the core emotion system (e.g., amygdala, right insula), whereas social inhibition correlated with a tendency to activate a broad cortical network (e.g., orbitofrontal cortex). Although tentative, these results suggest that social anxiety may be associated with enhanced processing of threatening or dominant postures.

STABLE FEATURES OF FACES, VOICES, AND BODIES

Another line of research explores the perception of stable characteristics (such as facial symmetry, vocal characteristics, and body size) as indicative of various psychological features (Tinlin et al., 2013). Substantial evidence indicates that people instantly form impressions from facial characteristics (e.g., Bar et al., 2006) and that these impressions affect important decisions (e.g., Olivola and Todorov, 2010). Regarding faces, individuals' facial maturity was linked to their perception as dominant. When baby-faced targets were paired with submissive information (congruent condition), they were better remembered than when they were paired with dominant (non-congruent) information (Cassidy et al., 2012). In addition, increase in men's face-width-to-height ratio was linked to their faces being perceived as more aggressive (Carré et al., 2010). Thus, stable facial characteristics appear influential in judgments of people as dominant and/or affiliative.

Studies with non-clinical populations have examined the influence of stable auditory characteristics of voice—especially pitch—on trait judgments. Specifically, male participants made judgments of likely physical aggressiveness based on vocal recordings of men reading a sentence, which were raised or lowered in both fundamental frequency (F0) and formant dispersion (df; Wolff and Puts, 2010). Raised vocal masculinity (lowered F0 or df) yielded higher dominance ratings. Moreover, raters with either high or low levels of testosterone rated other men as more dominant than raters with mean levels of testosterone.

Stable characteristics of body may also influence perceptions of power and dominance. Height is an important factor, as taller individuals were perceived as more dominant (Adams, 1980; Melamed, 1992; Young and French, 1998), even when females were evaluated (Boyson and Butler, 1999).

Recent studies from our group have shown that social anxiety is associated with biased impression formation and impression revision from trait descriptions (Aderka et al., 2013; Haker et al., 2013). Yet, to date, studies have yet to assess the role of social anxiety in the interpretation of static characteristics of the faces, voices, or bodies. Such an endeavor may enrich understanding of how social anxiety affects person perception.

INTEGRATED NONVERBAL REPRESENTATIONS

Integrating information from face, voice, and body plays a crucial role in human ability to understand social interactions. Although distinct, these different sources of information are normally processed in parallel, and, when synchronous, facilitate social comprehension. In contrast, the study of channel incongruity may enable understanding of the relative diagnostic value of each component of person perception. For example, participants predicted that the face would be most influential on perceptions of winning and losing emotions; however, the body was the best diagnostic feature (Aviezer et al., 2012). Rule et al. (2012) also found that face-body gestalt increased accuracy in perceiving dominance expressions from bodies and faces. Van den Stock et al. (2007) demonstrated that body postures conveying emotions influenced recognition of facial expressions and tones of voice. These findings emphasize the importance of emotional whole-body expressions, as well as the combination of NVSCs in everyday settings. With respect to social anxiety, the examination of conflicting cues—such as those connoting threat in one channel and affiliativeness in another—may elucidate the relative diagnosticity of each information type for socially anxious individuals.

EVALUATIVE SUMMARY OF NONVERBAL SOCIAL CUE (NVSC) PERCEPTION

Taken together, the research reviewed above suggests that individuals with high social anxiety are more likely than peers with low social anxiety to misinterpret EFEs and vocal expressions of emotions, although results pinpointing threatening misinterpretations were not as robust as theoretically expected. While pertinent studies on body posture are scarce, it appears likely that socially anxious individuals may be also biased in processing these stimuli. Examination of socially anxious individuals' perceptions of nonverbal representations of social status cues is important, given that social status is central to evolutionary (e.g., Gilbert and Trower, 2001), interpersonal (Alden and Taylor, 2004), and cognitive (e.g., Clark and Wells, 1995) accounts of social anxiety.

PRODUCTION OF NONVERBAL SOCIAL CUES (NVSCs)

Existing research has focused on NVSC perception, but multiple considerations indicate the need to extend investigation to the domain of NVSC production. First, examination of expressive indices of emotion can substantially complement subjective reports by linking research on adult humans to research on infants (Cappella, 1981) and non-human primates (e.g., Geerts and Brüne, 2009). Second, expressivity was pinpointed as an important clue for judging cooperation (e.g., Boone and Buck, 2003; Schug et al., 2010) and thus may direct an interaction's outcome. Third, based on embodied cognition accounts, researchers found that expressive behaviors lead to cognitive change (Briñol et al., 2011). These behavior-cognition and cognition-behavior links may generate either a self-enforcing positive or negative cycle, again influencing the course of interactions. Finally, NVSC production was shown to predict the long-term course of depression following treatment (Bos et al., 2006, 2007). Thus, NVSC production may possibly also be used to predict treatment outcomes in social anxiety.

FACES

Facial mimicry

Mimicry has been conceptualized as affiliative social behavior where one emulates another person's nonverbal actions (Lakin and Chartrand, 2003). By and large, mimicry was found to generate positive social feelings (Chartrand and Bargh, 1999). For example, priming individuals with prosocial (as opposed to antagonistic) goals generated more mimicking behavior (Leighton et al., 2010). Also, a priori manipulation of liking for another increased mimicry (Stel et al., 2010). Furthermore, automatic mimicry responses increased following a social exclusion situation, possibly because the threat of exclusion promoted affiliative motivations and actions (Lakin et al., 2008).

Importantly, mimicry depends on an interaction's nature; competitive interactions seem to elicit less facial mimicry than collaborative interactions (Likowski et al., 2011). Lower mimicry in competitive situations may be conceptualized as complementary behavior, where dominant displays (e.g., anger) elicit submissive reactions (e.g., fear). Interestingly, mimicry not only affects this social signal's recipient but also it's expresser: women were slower to recognize the affective valence of briefly displayed facial expressions when constrained from mimicking them (Stel and van Knippenberg, 2008). This effect was attributed to the fact that facial constraints hinder women's capacity to empathize.

Only a handful of studies explored automatic facial mimicry in social anxiety. In the first study to address this issue, Dimberg (1997) found that women high in public speaking fearfulness reacted with more frowning to angry faces than did women low in public speaking fearfulness, and women low in public speaking fearfulness exhibited more reactivity to happy facial expression than did women high in public speaking fearfulness (Dimberg, 1997). Vrana and Gross (2004) found that individuals high in public speaking fear exhibited more frowning in response to angry, neutral and happy facial expressions than did individuals low in speech fearfulness. Finally, Dimberg and Thunberg (2007) found that the individuals in a high public speaking fear group exhibited greater negative facial reactivity when responding to angry vs. happy faces, and greater positive emotional reactivity when responding to happy, as compared to angry faces. Given the recent emphasis on importance of mimicry for the establishment of rapport and liking on the one hand, and the deficits in affiliative behavior in social anxiety on the other (e.g., Alden and Taylor, 2011), more studies examining mimicry in social anxiety are needed.

Facial expressivity: voluntary displays of affect

Emotional expressivity is the extent to which an individual manifests emotional impulses behaviorally (Gross and John, 1997). Emotional expressivity was linked to increased positive affect (Gross and John, 1995; Burgin et al., 2012), whereas suppressing emotional displays was shown to decrease positive affect (Gross, 1998). Emotional expressivity was also linked to better social functioning (Burgin et al., 2012), cooperativeness (Schug et al., 2010), and agreeableness (Gross and John, 1995). Moreover, expressivity is beneficial not only when it concerns positive emotions. Feinberg et al. (2012) found that people who expressed embarrassment were judged as more prosocial. In terms of dominance, Hall et al. (2005) found that more gazing, nodding, and smiling and a generally more expressive face were associated with high interpersonal power.

Social anxiety is linked to lower levels of emotional expressivity (Kashdan and Breen, 2008), and is found to be mediated by beliefs that overt emotional expression is negative (Spokas et al., 2009). Moreover, Kashdan et al. (2011) found that the negative correlation between social anxiety and positive affect was mediated by the tendency to suppress emotional displays.

In sum, expressivity emerges as an important nonverbal variable in social interactions, signaling both dominant and affiliative propensities. Social anxiety is associated with lower levels of expressivity, constituting a potential deficiency in both social domains.

Eye gaze

Robust evidence suggests that avoidance of eye contact may be a central characteristic of SAD (e.g., Schneier et al., 2011). Specifically, fear and avoidance of eye contact consistently correlate with overall severity of social anxiety (e.g., Safren et al., 1999; Baker and Edelmann, 2002; Stein et al., 2004), and were recently found to decrease with successful treatment (e.g., Schneier et al., 2011). Studies relying on independent observers' judgments revealed that individuals with SAD made less eye contact during social interactions than individuals low in social anxiety (Baker and Edelmann, 2002; Voncken and Bögels, 2008). Advancements in eye-tracking methodology have permitted in-depth examination of this feature of socially anxious behavior: Individuals with SAD showed fewer gaze fixations on the eyes when facial expressions were presented for relatively long time intervals (e.g., Horley et al., 2004; Moukheiber et al., 2010, 2012; but see also Wieser et al., 2009).

Theoretically, gaze avoidance has been linked to submissive behavior in a variety of species (e.g., Mazur and Booth, 1998). Inasmuch as human social anxiety has been postulated as related to such submissive behaviors (e.g., Gilbert, 2001), perhaps gaze processing in social anxiety holds promise for creating a neurobiological marker of this disorder.

VOICE

Individuals with SAD are often concerned about showing auditory signs of anxiety during social performance (e.g., Hirsch and Clark, 2007). Early studies seeking to examine the veracity of these concerns tested the vocal performance of socially anxious individuals in interpersonal situations. Such highly socially anxious individuals were often rated by others as less competent in their vocal communication compared to controls (e.g., Borkovec et al., 1974; Fydrich et al., 1998; see review in Baker and Edelmann, 2002). Further studies highlighted relations between social anxiety and temporal features of spontaneous speech. For example, highly socially anxious and clinically distressed individuals with SAD paused more often and for longer durations, demonstrated slower speech rate, and evidenced restricted verbal output (e.g., Borkovec et al., 1973; Lewin et al., 1996; Hofmann et al., 1997).

In a pioneering study, Laukka et al. (2008) used acoustic analysis to explore the effect of social anxiety on objectively defined auditory parameters. Public speech samples of individuals with SAD were recorded preceding and following pharmacological intervention. Participants who reported lower anxiety following treatment demonstrated post-treatment decreases in mean F0 (subjectively perceived as pitch) and decreased proportions of silent pauses. In another study, Weeks et al. (2011) placed socially anxious men in a competitive interaction with another man over the positive attention of a female peer. Consistent with evolutionary predictions, highly socially anxious men manifested increased mean F0, whereas men low in social anxiety showed the opposite trend. Recently, Weeks et al. (2012) also compared acoustic characteristics of public speaking between a group with SAD and non-anxious controls. Males with SAD evidenced greater F0 in comparison to non-anxious individuals across both studies. For females, the inverse correlation between social anxiety and F0 was significant only when examined in patients with generalized SAD, and in response to in vivo social exposures. Importantly, gender-specific thresholds for mean F0 demonstrated excellent differentiation between patients with generalized SAD and non-anxious controls.

Galili et al. (2013) examined college students' vocal characteristics as a function of social anxiety by asking participants to record neutral, command, and request sentences and then analyzing these utterances' acoustic properties (mF0, intensity, speech rate, speech fluency). Social anxiety was associated with higher mF0 in men and women and with lesser vocal intensity in men. Moreover, compared to neutral sentences, social anxiety was associated with lesser increase of vocal intensity in command utterances, and with greater decrease of vocal intensity in request utterances. In men but not women, social anxiety also correlated with slower speech rate in request sentences. Taken together, these results pinpoint F0 as a promising biobehavioral marker of social anxiety (at least in men). Moreover, vocal intensity, speech rate, and speech fluency also seem likely to be affected by social anxiety in socially stressful situations.

Other nonverbal parameters of speech such as volubility (time spent talking; Mast, 2002; Brescoll, 2012), successful interruptions (Farley, 2008), vocal expressivity (e.g., Dunbar and Abra, 2010), initiation of speech acts, and laughter (Gifford and Hine, 1994) have been linked with high interpersonal power. Likewise, volubility was the best predictor of observer-rated social performance in an interaction task (Stevens et al., 2010). Similar findings emerged in an impromptu speech task, where socially phobic patients exhibited significantly less volubility than individuals low in social anxiety (Beidel et al., 2010).

In sum, different aspects of acoustic performance appear to link significantly with social anxiety. Acoustic parameters of speech associate closely with manifestations of power and social rank in both humans (e.g., Dunbar and Abra, 2010) and other mammals (e.g., Koren et al., 2008; Laporte and Zuberbühler, 2010). Altogether, these findings point to the possible diagnosticity of this expressive behavior.

POSTURE AND BODY MOVEMENT

Body posture and movement are important indicators of powerful behavior. Specifically, power is associated with more bodily openness, more erect or tense posture, and more body or leg shifts (Hall et al., 2005). Recently, Weeks et al. (2011) found that high social anxiety levels were associated with slumped and closed posture when interacting with a male competitor, whereas low social anxiety was associated with expansive posture. Other studies on observer ratings found that socially phobic individuals exhibited more bodily discomfort during social or performance tasks, such as rigidness and fidgeting (Voncken and Bögels, 2008; Heiser et al., 2009). Finally, measurement of observers' head movements showed that, when viewing an avatar's whole body, observers with high social anxiety mimicked the avatar significantly less than individuals with low social anxiety (Vrijsen et al., 2010).

EVALUATIVE SUMMARY OF NONVERBAL SOCIAL CUE (NVSC) PRODUCTION

Vocal and bodily behaviors appear linked to social anxiety and to expression of social rank. Facial expression and eye gaze seem linked both to expression of dominance (e.g., anger, contempt) and expression of affiliation (e.g., smiles). Existing research indicates that highly socially anxious individuals, especially males, will more likely exhibit submissive behaviors than individuals with low social anxiety.

Production of non-affiliative or submissive NVSCs is likely to deepen people's sense of disconnection and/or ineptitude either by directly influencing cognitions (e.g., Briñol et al., 2011) or through standards of culturally-appropriate behavioral norms (e.g., one should look one's offender in the eye, rather than lowering one's head; people should look others in the eye and smile). Thus, gaining more complete, complex understanding of NVSC production may advance more nuanced conceptualizations of interpersonal and situational factors that influence self-evaluations in social anxiety.

INTEGRATION OF THEORETICAL APPROACHES TO SOCIAL ANXIETY

NONVERBAL SOCIAL CUES (NVSCs) AT THE EPICENTER OF SOCIAL ENCOUNTERS

Independent theoretical contingents have identified different factors contributing to the maintenance of social anxiety: cognitions (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997; Gilbert, 2001; Hofmann et al., 2004), interpersonal factors (e.g., Alden and Taylor, 2004), or evolutionary pressures (Gilbert, 2001). Recent attempts were made to integrate these theoretical literatures. Our lab proposed a cognitive-evolutionary model (e.g., Aderka et al., 2013; Galili et al., 2013; Haker et al., 2013; Gilboa-Schechtman et al., in press), and several other researchers (Levinson et al., 2011; Taylor and Alden, 2011; Moscovitch et al., 2012) argued for a cognitive-interpersonal hypothesis. To varying degrees, the cognitive, interpersonal, and evolutionary models implicate abnormal social behavior and cognition in the onset and maintenance of social anxiety. Indeed, the three theories tend to be more complementary than contradictory. Importantly, all three postulate that socially anxious individuals are biased when perceiving social signals such as facial expressions, and because those signals guide interpersonal interactions, that bias leads to important outcomes. Interpersonal theories, evolutionary theories, and cognitive embodiment accounts also highlight the importance of the production of interpersonal signals (e.g., smiles, powerful postures) for the coordination of social interactions. Thus, the processing and production of NVSC is the juncture at which these theories intersect.

The evolutionary/interpersonal dimension of social rank and affiliation refine and sharpen the cognitive categories of threat and safety. Consider, for example, a case of an expanded pride posture (Tracy and Robins, 2004). While such posture may not represent social threat, it does connote an attempt to ascend in social rank. According to our account, such cues are likely to be selectively processed by individuals high in social anxiety. Conversely, the cognitive-embodiment account help explain the link between intra- and inter-personal mechanisms. For example, an assertive voice tone engenders a sense of self-assurance, which, in turn, elicits a complimentary (e.g., obliging, submissive) response from the interaction partner (e.g., Tiedens and Fragale, 2003). Moreover, we claim that the maintaining factors in social anxiety rely not only on the way individuals' process NVSC (the self-as-receiver of information) but also on the way individuals' *express* socially relevant attitudes and behavior (the self-as-an-agent).

REACTIVITY TO SOCIAL STRESS IN SOCIAL ANXIETY: NONVERBAL SOCIAL CUE (NVSC) AND BEYOND

Most theoretical models of SAD consider heightened sensitivity to, enhanced responsivity to, and impaired regulation in the face of social threat to be at the epicenter of this condition (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997; Gilbert and Trower, 2001; Hofmann et al., 2004). Individuals with SAD reported heightened emotional reactions to both positive and negative social events (e.g., Gilboa-Schechtman et al., 2000). Experimental interpersonal manipulation studies consistently found that individuals with high social anxiety or SAD reported more intense, persistent negative affect in anticipation of, and following, various social challenges such as public speaking (e.g., Rapee and Lim, 1992; Ly and Roelofs, 2009), social ostracism (Oaten et al., 2008) and social success (Wallace and Alden, 1997) compared to individuals with low social anxiety.

Research has yet to examine the impact of social anxiety on the sensitivity to and bias in interpreting NVSCs following social stress. As our review suggests, two types of distinct social events appear crucial for such future examination: events indicating changes in belongingness (e.g., social exclusion, gaining social favor) and events indicating changes in social rank (e.g., defeat, victory). Examination of sensitivity to diverse stressors is pivotal, as sensitivity to interpersonal cues signaling affiliation or social rank is essential for smooth navigation in the interpersonal world, especially when one seeks to recover from a social misfortune or to capitalize on social success. For example, following exclusion, a failure to correctly identify potential friends or allies (vs. foes) is likely to hamper social reintegration, thereby increasing the threat of additional rejection. Similarly, the failure to assert oneself once a social group observes one's positive qualities or deeds may hamper one's chances of advancing in the social hierarchy. Finally, the mediating effects of social anxiety on the tendency to interpret NVSCs as affiliative or dominant may elucidate the causal structure of attunement difficulties in this population.

FUTURE DIRECTIONS

The present perspective calls for several directions of future research. First, the current unified perspective accentuates the need to study gender differences in perceiving and perhaps even more so in expressing NVSCs. Men and women face somewhat different threats in navigating groups; women face greater risk for exclusion, whereas men face greater risk for physical defeat (e.g., Archer, 2004; Benenson et al., 2011). Thus, we can expect gender to moderate the relations between social anxiety and perception of exclusion and dominance signals, where women are more sensitive to exclusion and men to dominance. Moreover, based on the tend-and-befriend theory of women's response to social threat, females may be expected to engage in more affiliative gestures following exclusion or defeat, whereas men may be more likely to express signals of deference or submissiveness (Taylor, 2006).

Second, existing evidence points to the possibility that embodiment of powerful NVSCs may lead to congruent changes in cognitions and cognitive processing and, conversely, the adoption of submissive NVSCs may deepen existing cognitive biases. For example, recent studies by Galinsky et al. (2006) suggested that merely thinking about powerful experiences enhances performance (Lammers et al., 2013). Moreover, both power postures and power roles were shown to reduce interpersonal fearfulness and increase approach behaviors; yet, power postures were more effective (Huang and Galinsky, 2010). Similarly, recent studies found that pitch does not merely correlate with social rank—it also instills subjective feelings of dominance and cognitive correlates of power (Stel et al., 2012). Altogether, these studies suggest reciprocal patterns of influence between NVSCs and cognition, with dominant expressions enhancing sense of power and submissive expressions decreasing it. Thus, loss of felt power may result in fewer displays of expressive behaviors in general and greater displays of submissive or appeasement behaviors (Stel et al., 2012). Such changes in expressive production may foster self-perceptions of powerlessness. These findings underscore an intriguing possibility for embodiment-focused cognitive interventions, such that socially anxious individuals may engage in training to implicitly or explicitly affect their sense of power or dominance.

Finally, research on NVSCs may provide converging evidence regarding the brain circuits engaged in social anxiety. For example, if processing of several types of NVSCs is found to involve overlapping circuitry (amygdala, insula, DLPFC), such brain areas may be associated with a special significance for social anxiety. More broadly, focusing on the social rank and affiliation systems may offer a new and helpful conceptual framework to examine brain mechanisms previously labeled approach-related and avoidance-related (e.g., Quirin et al., 2013; Terburg and van Honk, 2013).

CONCLUSION

NVSC are signals with long evolutionary history. As such they figured prominently in cognitive, interpersonal, and evolutionary accounts. In the present review we emphasized the links between biased processing of NVSC and social anxiety, highlighting the tendency of the socially anxious to be sensitive to social status cues. We also emphasized that production of non-affiliative or submissive NVSCs is likely to deepen a sense of disconnection and ineptitude. Given these propensities, socially anxious individuals might perceive and remember the social world as a hierarchical and competitive arena. These perceptions, in turn, may lead to a persistent sense of incompetence and inferiority (Gilbert et al., 2009). In the review we emphasized the interplay between perception and expression of NVSC as concomitant with social anxiety; future work would profit from examining the causal status of NVSC as contributing to the onset and maintenance of this condition.

REFERENCES

Adams, G. R. (1980). Social psychology of beauty: effects of age, height and weight on self-reported personality traits and social behavior. *J. Soc. Psychol.* 112, 287–293. doi: 10.1080/00224545.1980.9924330

Aderka, I. M., Haker, A., Marom, S., Hermesh, H., and Gilboa-Schechtman, E. (2013). Information-seeking bias in social anxiety disorder. *J. Abnorm. Psychol.* 122, 7–12. doi: 10.1037/a0029555

Aderka, I. M., Hofmann, S. G., Nickerson, A., Hermesh, H., Gilboa-Schechtman, E., and Marom, S. (2012). Functional impairment in social anxiety disorder. *J. Anxiety Disord.* 26, 393–400. doi: 10.1016/j.janxdis.2012.01.003

Aderka, I. M., Weisman, O., Shahar, G., and Gilboa-Schechtman, E. (2009). The roles of the social rank and attachment systems in social anxiety. *Pers. Individ. Dif.* 47, 284–288. doi: 10.1016/j.paid.2009.03.014

Alden, L. E., and Taylor, C. T. (2011). Relational treatment strategies increase social approach behaviors in patients with generalized social anxiety disorder. *J. Anxiety Disord.* 25, 309–318. doi: 10.1016/j.janxdis.2010.10.003

Alden, L. E., and Taylor, C. T. (2004). Interpersonal processes in social phobia. *Clin. Psychol. Rev.* 24, 857–882. doi: 10.1016/j.cpr.2004.07.006

App, B., McIntosh, D. N., Reed, C. L., and Hertenstein, M. J. (2011). Nonverbal channel use in communication of emotion: how may depend on why. *Emotion* 11, 603–617. doi: 10.1037/a0023164

App, B., Reed, C. L., and McIntosh, D. N. (2012). Relative contributions of face and body configurations: perceiving emotional state and motion intention. *Cogn. Emot.* 26, 690–698. doi: 10.1080/02699931.2011.588688

Archer, J. (2004). Sex differences in aggression in real-world settings: a meta-analytic review. *Rev. Gen. Psychol.* 8, 291–322. doi: 10.1037/1089-2680.8.4.291

Archer, J. (2006). Testosterone and human aggression: an evaluation of the challenge hypothesis. *Neurosci. Biobehav. Rev.* 30, 319–345. doi: 10.1016/j.neubiorev.2004.12.007

Argyle, M., Salter, V., Nicholson, H., Williams, M., and Burgess, P. (1970). The communication of inferior and superior attitudes by verbal and non-verbal signals. *Br. J. Soc. Clin. Psychol.* 9, 222–231. doi: 10.1111/j.2044-8260.1970.tb00668.x

Arrais, K. C., Machado-de-Sousa, J., Trzesniak, C., Santos Filho, A., Ferrari, M. C. F., Osório, F. L., et al. (2010). Social anxiety disorder women easily recognize fearfull, sad and happy faces: the influence of gender. *J. Psychiatr. Res.* 44, 535–540. doi: 10.1016/j.jpsychires.2009.11.003

Aviezer, H., Trope, Y., and Todorov, A. (2012). Body cues, not facial expressions, discriminate between intense positive and negative emotions. *Science* 338, 1225–1229. doi: 10.1126/science.1224313

Baker, S. R., and Edelmann, R. J. (2002). Is social phobia related to lack of social skills? Duration of skill-related behaviours and ratings of behavioural adequacy. *Br. J. Clin. Psychol.* 41, 243–257. doi: 10.1348/014466502760379118

Bar, M., Neta, M., and Linz, H. (2006). Very first impressions. *Emotion* 6, 269–278. doi: 10.1037/1528-3542.6.2.269

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* 117, 497–529. doi: 10.1037//0033-2909.117.3.497

Beasley, M., Sabatinelli, D., and Obasi, E. (2012). Neuroimaging evidence for social rank theory. *Front. Hum. Neurosci.* 6:123. doi: 10.3389/fnhum.2012.00123

Beidel, D. C., Rao, P. A., Scharfstein, L., Wong, N., and Alfano, C. A. (2010). Social skills and social phobia: an investigation of DSM-IV subtypes. *Behav. Res. Ther.* 48, 992–1001. doi: 10.1016/j.brat.2010.06.005

Benenson, J. F., Markovits, H., Thompson, M. E., and Wrangham, R. W. (2011). Under threat of social exclusion, females exclude more than males. *Psychol. Sci.* 22, 538–544. doi: 10.1177/0956797611402511

Birbaumer, N., Grodd, W., Diedrich, O., Klose, U., Erb, M., Lotze, M., et al. (1998). fMRI reveals amygdala activation to human faces in social phobics. *Neuroreport* 9, 1223–1226. doi: 10.1097/00001756-199804200-00048

Bistricky, S. L., Ingram, R. E., and Atchley, R. A. (2011). Facial affect processing and depression susceptibility: cognitive biases and cognitive neuroscience. *Psychol. Bull.* 137, 998–1028. doi: 10.1037/a0025348

Boone, R., and Buck, R. (2003). Emotional expressivity and trustworthiness: the role of nonverbal behavior in the evolution of cooperation. *J. Nonverbal Behav.* 27, 163–182. doi: 10.1023/A:1025341931128

Borkovec, T. D., Fleischmann, D. J., and Caputo, J. A. (1973). The measurement of anxiety in an analogue social situation. *J. Consult. Clin. Psychol.* 41, 157–161. doi: 10.1037/h0035579

Borkovec, T. D., Stone, N. M., O'Brien, G. T., and Kaloupek, D. G. (1974). Evaluation of a clinically relevant target behavior for analog outcome research. *Behav. Ther.* 5, 503–513. doi: 10.1016/S0005-7894(74)80040-7

Bos, E. H., Bouhuys, A. L., Geerts, E., Van Os, T. W. D. P., and Ormel, J. (2006). Lack of association between conversation partners' nonverbal behavior predicts recurrence of depression, independently of personality. *Psychiatry Res.* 142, 79–88. doi: 10.1016/j.psychres.2005.05.015

Bos, E. H., Bouhuys, A. L., Geerts, E., Van Os, T. W. D. P., and Ormel, J. (2007). Stressful life events as a link between problems in nonverbal communication and recurrence of depression. *J. Affect. Disord.* 97, 161–169. doi: 10.1016/j.jad.2006.06.011

Boyson, A. R., and Butler, J. (1999). Height as power in women. *N. Am. J. Psychol.* 1, 109–114.

Brescoll, V. L. (2012). Who takes the floor and why: gender, power and volubility in organizations. *Adm. Sci. Quart.* 56, 622–641. doi: 10.1177/0001839212439994

Briñol, P., Petty, R., and Wagner, B. (2011). Embodied attitude change: a self validation perspective. *Soc. Personal.* 12, 1039–1050. doi: 10.1111/j.1751-9004.2011.00402.x

Buck, R. (1984). *The Communication of Emotion*. New York: Guilford Press.

Buck, R., and Vanlear, C. A. (2002). Verbal and nonverbal communication: distinguishing symbolic, spontaneous and pseudo-spontaneous nonverbal behavior. *J. Commun.* 52, 522–541. doi: 10.1111/j.1460-2466.2002.tb02560.x

Buckner, J. D., Maner, J. K., and Schmidt, N. B. (2010). Difficulty disengaging attention from social threat in social anxiety. *Cognit. Ther. Res.* 34, 99–105. doi: 10.1007/s10608-008-9205-y

Bugental, D. (2000). Acquisition of the algorithms of social life: a domain-based approach. *Psychol. Bull.* 126, 187–219. doi: 10.1037//0033-2909.126.2.187

Burgin, C. J., Brown, L. H., Royal, A., Silvia, P. J., Barrantes-Vidal, N., and Kwapil, T. R. (2012). Being with others and feeling happy: emotional expressivity in everyday life. *Pers. Individ. Dif.* 53, 185–190. doi: 10.1016/j.paid.2012.03.006

Campbell, D. W., Sareen, J., Stein, M. B., Kravetsky, L. B., Paulus, M. P., Hassard, S. T., et al. (2009). Happy but not so approachable: the social judgments of individuals with generalized social phobia. *Depress. Anxiety* 26, 419–424. doi: 10.1002/da.20474

Cappella, J. N. (1981). Mutual influence in expressive behavior: adult–adult and infant–adult dyadic interaction. *Psychol. Bull.* 89, 101–132. doi: 10.1037/0033-2909.89.1.101

Cardoso, C., Linnen, A.-M., Joober, R., and Ellenbogen, M. A. (2012). Coping style moderates the effect of intranasal oxytocin on the mood response to interpersonal stress. *Exp. Clin. Psychopharmacol.* 20, 84–91. doi: 10.1037/a0025763

Carney, D. R., Cuddy, A. J. C., and Yap, A. J. (2010). Power posing: brief nonverbal displays affect neuroendocrine levels and risk tolerance. *Psychol. Sci.* 21, 1363–1368. doi: 10.1177/0956797610383437

Carré, J. M., Morrissey, M. D., Mondloch, C. J., and McCormick, C. M. (2010). Estimating aggression from emotionally neutral faces: which facial cues are diagnostic? *Perception* 39, 356–377. doi: 10.1068/p6543

Cassidy, B. S., Zebrowitz, L. A., and Gutchess, A. H. (2012). Appearance-based inferences bias source memory. *Mem. Cognit.* 40, 1214–1224. doi: 10.3758/s13421-012-0233-1

Chartrand, T. L., and Bargh, J. A. (1999). The chameleon effect: the perception-behavior link and social interaction. *J. Pers. Soc. Psychol.* 76, 893–910. doi: 10.1037//0022-3514.76.6.893

Chen, N. T. M., Clarke, P. J. F., MacLeod, C., and Guastella, A. J. (2012). Biased attentional processing of positive stimuli in social anxiety disorder: an eye movement study. *Cogn. Behav. Ther.* 41, 96–107. doi: 10.1080/16506073.2012.666562

Chiao, J. Y., Harada, T., Oby, E. R., Li, Z., Parrish, T., and Bridge, D. J. (2009). Neural representations of social status hierarchy in human inferior parietal cortex. *Neuropsychologia* 47, 354–363. doi: 10.1016/j.neuropsychologia.2008.09.023

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Social Phobia: Diagnosis, Assessment and Treatment*, eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope and F. R. Schneier (New York, NY: Guilford Press), 69–93.

Coles, M. E., and Heimberg, R. G. (2002). Memory biases in the anxiety disorders: current status. *Clin. Psychol. Rev.* 22, 587–627. doi: 10.1142/9789812776563_0041

Cozolino, L. (2002). *The Neuroscience of Psychotherapy: Building and Rebuilding the Human Brain*. New York, NY: WW Norton & Company.

Cuming, S., and Rapee, R. M. (2010). Social anxiety and self-protective communication style in close relationships. *Behav. Res. Ther.* 48, 87–96. doi: 10.1016/j.brat.2009.09.010

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

Dewall, C. N., Macdonald, G., Webster, G. D., Masten, C. L., Baumeister, R. F., Powell, C., et al. (2010). Acetaminophen reduces social pain: behavioral and neural evidence. *Psychol. Sci.* 21, 931–937. doi: 10.1177/0956797610374741

Dimberg, U. (1997). Social fear and expressive reactions to social stimuli. *Scand. J. Psychol.* 38, 171–174. doi: 10.1111/1467-9450.00024

Dimberg, U., and Thunberg, M. (2007). Speech anxiety and rapid emotional reactions to angry and happy facial expressions. *Scand. J. Psychol.* 48, 321–328. doi: 10.1111/j.1467-9450.2007.00586.x

Donohue, S. E., Liotti, M., Perez, R., and Woldorff, M. G. (2012). Is conflict monitoring supramodal? Spatiotemporal dynamics of cognitive control processes in an auditory Stroop task. *Cogn. Affect. Behav. Neurosci.* 12, 1–15. doi: 10.3758/s13415-011-0060-z

Douilliez, C., Yzerbyt, V., Gilboa-Schechtman, E., and Philippot, P. (2012). Social anxiety biases the evaluation of facial displays: evidence from single face and multi-facial stimuli. *Cogn. Emot.* 26, 1107–1115. doi: 10.1080/02699931.2011.632494

Dunbar, N. E., and Abra, G. (2010). Observations of dyadic power in interpersonal interaction. *Commun. Monogr.* 77, 657–684. doi: 10.1080/03637751.2010.520018

Eisenberger, N. I., Lieberman, M. D., and Williams, K. D. (2003). Does rejection hurt? An FMRI study of social exclusion. *Science* 302, 290–292. doi: 10.1126/science.1089134

Ellyson, L., and Steve, J. F. D. (1985). "Power, dominance and nonverbal behavior: basic concepts and issues," in *Power, Dominance and Nonverbal Behavior*, eds S. L. Ellyson and J. F. Davifio (New York: Springer), 1–27.

Eng, W., Coles, M. E., Heimberg, R. G., and Safren, S. A. (2005). Domains of life satisfaction in social anxiety disorder: relation to symptoms and response to cognitive-behavioral therapy. *J. Anxiety Disord.* 19, 143–156. doi: 10.1016/j.janxdis.2004.01.007

Evans, K. C., Wright, C. I., Wedig, M. M., Gold, A. L., Pollack, M. H., and Rauch, S. L. (2008). A functional MRI study of amygdala responses to angry schematic faces in social anxiety disorder. *Depress. Anxiety* 25, 496–505. doi: 10.1002/da.20347

Farley, S. D. (2008). Attaining status at the expense of likeability: pilfering power through conversational interruption. *J. Nonverbal Behav.* 32, 241–260. doi: 10.1007/s10919-008-0054-x

Farley, S. D., Hughes, S. M., and LaFayette, J. N. (2013). People will know we are in love: evidence of differences between vocal samples directed toward lovers and friends. *J. Nonverbal Behav.* 37, 123–138. doi: 10.1007/s10919-013-0151-3

Feinberg, M., Willer, R., and Keltner, D. (2012). Flustered and faithful: embarrassment as a signal of prosociality. *J. Pers. Soc. Psychol.* 102, 81–97. doi: 10.1037/a0025403

Feldman, R. (2012). Oxytocin and social affiliation in humans. *Horm. Behav.* 61, 380–391. doi: 10.1016/j.yhbeh.2012.01.008

Feldman, R., and Eidelman, A. I. (2007). Maternal postpartum behavior and the emergence of infant – mother and infant – father synchrony in preterm and full-term infants: the role of neonatal vagal tone. *Dev. Psychobiol.* 49, 290–302. doi: 10.1002/dev.20220

Foa, E. B., Gilboa-Schechtman, E., Amir, N., and Freshman, M. (2000). Memory bias in generalized social phobia: remembering negative emotional expressions. *J. Anxiety Disord.* 14, 501–519. doi: 10.1016/S0887-6185(00)00036-0

Frijda, N. H. (1986). *The Emotions*. New York, NY: Cambridge University Press.

Fydrich, T., Chambless, D. L., Perry, K. J., Buergener, F., and Beazley, M. B. (1998). Behavioral assessment of social performance: a rating system for social phobia. *Behav. Res. Ther.* 36, 995–1010. doi: 10.1016/s0005-7967(98)00069-2

Galili, L., Amir, O., and Gilboa-Schechtman, E. (2013). Acoustic properties of dominance and help seeking utterances in social anxiety. *J. Soc. Clin. Psychol.* 32, 651–673. doi: 10.1521/jscp.2013.32.6.651

Galinsky, A. D., Magee, J. C., Inesi, M. E., and Gruenfeld, D. H. (2006). Power and perspectives not taken. *Psychol. Sci.* 17, 1068–1074. doi: 10.1111/j.1467-9280.2006.01824.x

Geerts, E., and Brüne, M. (2009). Ethological approaches to psychiatric disorders: focus on depression and schizophrenia. *Aust. N.Z.J. Psychiatry* 43, 1007–1015. doi: 10.3109/00048670903270498

Gifford, R., and Hine, D. (1994). The role of verbal behavior in the encoding and decoding of interpersonal dispoitions. *J. Res. Pers.* 28, 115–132. doi: 10.1006/jrpe.1994.1010

Gilbert, P. (2001). Evolution and social anxiety: the role of attraction, social competition and social hierarchies. *Psychiatr. Clin. North Am.* 24, 723–751. doi: 10.1016/S0193-953X(05)70260-4

Gilbert, P., McEwan, K., and Bellew, R. (2009). The dark side of competition: how competitive behaviour and striving to avoid inferiority are linked to depression, anxiety, stress and self - harm. *Psychol. Psychother.* 82, 123–136. doi: 10.1348/147608308X379806

Gilbert, P., and Trower, P. (2001). "Evolution and process in social anxiety," in *International Handbook of Social Anxiety: Concepts, Research and Interventions Relating to the Self and Shyness*, eds W. R. Crozier and L. Alden (New York, NY, US: John Wiley & Sons Ltd), 259–279.

Gilboa-Schechtman, E., Foa, E., and Amir, N. (1999). Attentional biases for facial expressions in social phobia: the face-in-the-crowd paradigm. *Cogn. Emot.* 13, 305–318. doi: 10.1080/026999399379294

Gilboa-Schechtman, E., Foa, E., Vaknin, Y., Marom, S., and Hermesh, H. (2008). Interpersonal sensitivity and response bias in social phobia and depression: labeling emotional expressions. *Cognit. Ther. Res.* 32, 605–618. doi: 10.1007/s10608-008-9208-8

Gilboa-Schechtman, E., Franklin, M. E., and Foa, E. (2000). Anticipated reactions to social events: differences among individuals with generalized social phobia, obsessive compulsive disorder and nonanxious controls. *Cognit. Ther. Res.* 24, 731–746. doi: 10.1023/A:1005595513315

Gilboa-Schechtman, E., Presburger, G., Marom, S., and Hermesh, H. (2005). The effects of social anxiety and depression on the evaluation of facial crowds. *Behav. Res. Ther.* 43, 467–474. doi: 10.1016/j.brat.2004.03.001

Gilboa-Schechtman, E., Shachar, I., and Sahar, Y. (in press). "Positivity impairment as a broad-based feature of social anxiety," in *Handbook on Social Anxiety Disorder*, ed J. Weeks (New York: Wiley-Blackwell).

Gliga, T., and Dehaene-Lambertz, G. (2005). Structural encoding of body and face in human infants and adults. *J. Cogn. Neurosci.* 17, 1328–40. doi: 10.1162/0898929055002481

Gotlib, I. H., Krasnoperova, E., Yue, D. N., and Joormann, J. (2004). Attentional biases for negative interpersonal stimuli in clinical depression. *J. Abnorm. Psychol.* 113, 127–135. doi: 10.1037/0021-843x.113.1.121

Gross, J. J. (1998). Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression and physiology. *J. Pers. Soc. Psychol.* 74, 224–237. doi: 10.1037//0022-3514.74.1.224

Gross, J. J., and John, O. P. (1995). Facets of emotional expressivity: three self-report factor and their correlates. *Pers. Individ. Dif.* 19, 555–568. doi: 10.1016/0191-8869(95)00055-b

Gross, J. J., and John, O. P. (1997). Revealing feelings: facets of emotional expressivity in self-reports, peer ratings and behavior. *J. Pers. Soc. Psychol.* 72, 435–448. doi: 10.1037/0022-3514.72.2.435

Guastella, A. J., Mitchell, P. B., and Dadds, M. R. (2008). Oxytocin increases gaze to the eye region of human faces. *Biol. Psychiatry* 63, 3–5. doi: 10.1016/j.biopsych.2007.06.026

Haker, A., Aderka, I. M., Marom, S., Hermesh, H., and Gilboa-Schechtman, E. (2013). Impression formation and revision in social anxiety disorder. *J. Anxiety Disord.* doi: 10.1016/j.janxdis.2013.05.001. [Epub ahead of print].

Hall, J., Coats, E. J., and LeBeau, L. S. (2005). Nonverbal behavior and the vertical dimension of social relations: a meta-analysis. *Psychol. Bull.* 131, 898–924. doi: 10.1037/0033-2909.131.6.898

Heiser, N. A., Turner, S. M., Beidel, D. C., and Roberson-Nay, R. (2009). Differentiating social phobia from shyness. *J. Anxiety Disord.* 23, 469–476. doi: 10.1016/j.janxdis.2008.10.002

Heuer, K., Lange, W.-G., Isaac, L., Rinck, M., and Becker, E. S. (2010). Morphed emotional faces: emotion detection and misinterpretation in social anxiety. *J. Behav. Ther. Exp. Psychiatry* 41, 418–425. doi: 10.1016/j.jbtep.2010.04.005

Heuer, K., Rinck, M., and Becker, E. S. (2007). Avoidance of emotional facial expressions in social anxiety: the approach-avoidance task. *Behav. Res. Ther.* 45, 2990–3001. doi: 10.1016/j.brat.2007.08.010

Hirsch, C. R., and Clark, D. M. (2007). Imagery special issue: underestimation of auditory performance in social phobia and the use of audio feedback. *J. Behav. Ther. Exp. Psychiatry* 38, 447–458. doi: 10.1016/j.jbtep.2007.08.004

Hofmann, S. G., Gerlach, A. L., Wender, A., and Roth, W. T. (1997). Speech disturbances and gaze behavior during public speaking in subtypes of social phobia. *J. Anxiety Disord.* 11, 573–585. doi: 10.1016/s0887-6185(97)00040-6

Hofmann, S. G., Heinrichs, N., and Moscovitch, D. A. (2004). The nature and expression of social phobia: toward a new classification. *Clin. Psychol. Rev.* 24, 769–797. doi: 10.1016/j.cpr.2004.07.004

Horley, K., Williams, L. M., Gonsalvez, C., and Gordon, E. (2004). Face to face: visual scanpath evidence for abnormal processing of facial expressions in social phobia. *Psychiatry Res.* 127, 43–53. doi: 10.1016/j.psychres.2004.02.016

Huang, L., and Galinsky, A. D. (2010). No mirrors for the powerful: why dominant smiles are not processed using embodied simulation. *Behav. Brain Sci.* 33, 448. doi: 10.1017/s0140525x10001536

Itier, R. J., and Batty, M. (2009). Neural bases of eye and gaze processing: the core of social cognition. *Neurosci. Biobehav. Rev.* 33, 843–863. doi: 10.1016/j.neubiorev.2009.02.004

Jacob, H., Kreifelts, B., Brück, C., Erb, M., Hösl, F., and Wildgruber, D. (2012). Cerebral integration of verbal and nonverbal emotional cues: impact of individual nonverbal dominance. *Neuroimage* 61, 738–747. doi: 10.1016/j.neuroimage.2012.03.085

Johnson, S. L., Leedom, L. J., and Muhtadie, L. (2012). The dominance behavioral system and psychopathology: evidence from self-report, observational and biological studies. *Psychol. Bull.* 138, 692–743. doi: 10.1037/a0027503

Joormann, J., and Gotlib, I. H. (2006). Is this happiness i see? Biases in the identification of emotional facial expressions in depression and social phobia. *J. Abnorm. Psychol.* 115, 705–714. doi: 10.1037/0021-843x.115.4.705

Kachin, K. E., Newman, M. G., and Pincus, A. L. (2001). An interpersonal problem approach to the division of social phobia subtypes. *Behav. Ther.* 32, 479–501. doi: 10.1016/s0005-7894(01)80032-0

Kashdan, T. B., and Breen, W. E. (2008). Social anxiety and positive emotions: a prospective examination of a self-regulatory model with tendencies to suppress or express emotions as a moderating variable. *Behav. Ther.* 39, 1–12. doi: 10.1016/j.beth.2007.02.003

Kashdan, T. B., Weeks, J. W., and Savostyanova, A. A. (2011). Whether, how and when social anxiety shapes positive experiences and events: a self-regulatory framework and treatment implications. *Clin. Psychol. Rev.* 31, 786–799. doi: 10.1016/j.cpr.2011.03.012

Knutson, B. (1996). Facial expressions of emotion influence interpersonal trait inferences. *J. Nonverbal Behav.* 20, 165–182. doi: 10.1007/BF02281954

Kolassa, I.-T., Kolassa, S., Bergmann, S., Lauche, R., Dilger, S., Miltner, W. H. R., et al. (2009). Interpretive bias in social phobia: an ERP study with morphed emotional schematic faces. *Cogn. Emot.* 23, 69–95. doi: 10.1080/02699930801940461

Kolassa, I.-T., Kolassa, S., Musial, F., and Miltner, W. H. R. (2007). Event-related potentials to schematic faces in social phobia. *Cogn. Emot.* 21, 1721–1744. doi: 10.1080/02699930701229189

Kolassa, I.-T., and Miltner, W. H. R. (2006). Psychophysiological correlates of face processing in social phobia. *Brain Res.* 1118, 130–141. doi: 10.1016/j.brainres.2006.08.019

Koren, L., Mokady, O., and Geffen, E. (2008). Social status and cortisol levels in singing rock hyraxes. *Horm. Behav.* 54, 212–216. doi: 10.1016/j.yhbeh.2008.02.020

Kret, M. E., Denollet, J., Grèzes, J., and de Gelder, B. (2011). The role of negative affectivity and social inhibition in perceiving social threat: an fMRI study. *Neuropsychologia* 49, 1187–1193. doi: 10.1016/j.neuropsychologia.2011.02.007

Lakin, J. L., and Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychol. Sci.* 14, 334–339. doi: 10.1111/1467-9280.14481

Lakin, J., Chartrand, T. L., and Arkin, R. (2008). I am too just like you: nonconscious mimicry as an automatic behavioral response to social exclusion. *Psychol. Sci.* 19, 816–822. doi: 10.1111/j.1467-9280.2008.02162.x

Lammers, J., Dubois, D., Rucker, D. D., and Galinsky, A. D. (2013). Power gets the job: priming power improves interview outcomes. *J. Exp. Soc. Psychol.* 49, 776–779. doi: 10.1016/j.jesp.2013.02.008

Lange, W.-G., Heuer, K., Langner, O., Keijsers, G. P. J., Becker, E. S., and Rinck, M. (2011). Face value: eye movements and the evaluation of facial crowds in social anxiety. *J. Behav. Ther. Exp. Psychiatry* 42, 355–363. doi: 10.1016/j.jbtep.2011.02.007

Laporte, M. N. C., and Zuberbühler, K. (2010). Vocal greeting behaviour in wild chimpanzee females. *Anim. Behav.* 80, 467–473. doi: 10.1016/j.anbehav.2010.06.005

Laukka, P., Linnman, C., Åhs, F., Pissiota, A., Frans, Ö., Faria, V., et al. (2008). In a nervous voice: acoustic analysis and perception of anxiety in social phobics' speech. *J. Nonverbal Behav.* 32, 195–214. doi: 10.1007/s10919-008-0055-9

Leighton, J., Bird, G., Orsini, C., and Heyes, C. (2010). Social attitudes modulate automatic imitation. *J. Exp. Soc. Psychol.* 46, 905–910. doi: 10.1016/j.jesp.2010.07.001

Leppänen, J. M., and Hietanen, J. K. (2001). Emotion recognition and social adjustment in school–aged girls and boys. *Scand. J. Psychol.* 42, 429–435. doi: 10.1111/1467-9450.00255

Levinson, C. A., Langer, J. K., and Rodebaugh, T. L. (2011). Self-construal and social anxiety: considering personality. *Pers. Individ. Dif.* 51, 355–359. doi: 10.1016/j.paid.2011.04.006

Lewin, M. R., McNeil, D. W., and Lipson, J. M. (1996). Enduring without avoiding: pauses and verbal dysfluencies in public speaking fear. *J. Psychopathol. Behav. Assess.* 18, 387–402. doi: 10.1007/bf02229142

Liang, C.-W., Hsu, W.-Y., Hung, F.-C., Wang, W.-T., and Lin, C.-H. (2011). Absence of a positive bias in social anxiety: the application of a directed forgetting paradigm. *J. Behav. Ther. Exp. Psychiatry* 42, 204–210. doi: 10.1016/j.jbtep.2010.12.002

Likowski, K. U., Mühlberger, A., Seibt, B., Pauli, P., and Weyers, P. (2011). Processes underlying congruent and incongruent facial reactions to emotional facial expressions. *Emotion* 11, 457–467. doi: 10.1037/a0023162

Linnen, A.-M., Ellenbogen, M. A., Cardoso, C., and Joober, R. (2012). Intranasal oxytocin and salivary cortisol concentrations during social rejection in university students. *Stress* 15, 393–402. doi: 10.3109/10253890.2011.631154

Ly, V., and Roelofs, K. (2009). Social anxiety and cognitive expectancy of aversive outcome in avoidance conditioning. *Behav. Res. Ther.* 47, 840–847. doi: 10.1016/j.brat.2009.06.015

Magee, J. C., and Galinsky, A. D. (2008). Social hierarchy: the self reinforcing nature of power and status. *Acad. Manag. Ann.* 2, 351–398. doi: 10.1080/19416520802211628

Mast, M. S. (2002). Dominance as expressed and inferred through speaking time. *Hum. Commun. Res.* 28, 420–450. doi: 10.1093/hcr/28.3.420

Mazur, A., and Booth, A. (1998). Testosterone and dominance in men. *Behav. Brain Sci.* 21, 353–363; discussion 363–397. doi: 10.1017/s0140525x98001228

McClure, E. B., and Nowicki, S. (2001). Associations between social anxiety and nonverbal processing skill in preadolescent boys and girls. *J. Nonverbal Behav.* 25, 3–19. doi: 10.1023/A:1006753006870

Mehrabian, A. (1970). A semantic space for nonverbal behavior. *J. Consult. Clin. Psychol.* 35, 248–257. doi: 10.1037/h0030083

Melamed, T. (1992). Personality correlates of physical height. *Pers. Individ. Dif.* 13, 1349–1350. doi: 10.1016/0191-8869(92)90179-s

Mignault, A., and Chaudhuri, A. (2003). The many faces of a neutral face: head tilt and perception of dominance and emotion. *J. Nonverbal Behav.* 27, 111–132. doi: 10.1023/A:1023914509763

Moors, A., and De Houwer, J. (2005). Automatic processing of dominance and submissiveness. *Exp. Psychol.* 52, 296–302. doi: 10.1027/1618-3169.52.4.296

Moriya, J., and Tanno, Y. (2011). The time course of attentional disengagement from angry faces in social anxiety. *J. Behav. Ther. Exp. Psychiatry* 42, 122–128. doi: 10.1016/j.jbtep.2010.08.001

Moscovitch, D. A., Rodebaugh, T. L., and Hesch, B. D. (2012). How awkward! Social anxiety and the perceived consequences of social blunders. *Behav. Res. Ther.* 50, 142–149. doi: 10.1016/j.brat.2011.11.002

Moukheiber, A., Rautureau, G., Perez-Diaz, F., Jouvent, R., and Pelissolo, A. (2012). Gaze behaviour in social blushers. *Psychiatry Res.* 200, 614–619. doi: 10.1016/j.psychres.2012.07.017

Moukheiber, A., Rautureau, G., Perez-Diaz, F., Soussignan, R., Dubal, S., Jouvent, R., et al. (2010). Gaze avoidance in social phobia: objective measure and correlates. *Behav. Res. Ther.* 48, 147–151. doi: 10.1016/j.brat.2009.09.012

Mühlberger, A., Wieser, M. J., Herrmann, M. J., Weyers, P., Tröger, C., and Pauli, P. (2009). Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. *J. Neural. Transm.* 116, 735–746. doi: 10.1007/s00702-008-0108-6

Muscatell, K. A., Morelli, S. A., Falk, E. B., Way, B. M., Pfeifer, J. H., Galinsky, A. D., et al. (2012). Social status modulates neural activity in the mentalizing network. *Neuroimage* 60, 1771–1777. doi: 10.1016/j.neuroimage.2012.01.080

Nakao, T., Sanematsu, H., Yoshiura, T., Togao, O., Murayama, K., Tomita, M., et al. (2011). fMRI of patients with social anxiety disorder during a social situation task. *Neurosci. Res.* 69, 67–72. doi: 10.1016/j.neures.2010.09.008

Oaten, M., Williams, K. D., Jones, A., and Zadro, L. (2008). The effects of ostracism on self–regulation in the socially anxious. *J. Soc. Clin. Psychol.* 27, 471–504. doi: 10.1521/jscp.2008.27.5.471

Olivola, C. Y., and Todorov, A. (2010). Elected in 100 milliseconds: appearance-based trait inferences and voting. *J. Nonverbal Behav.* 34, 83–110. doi: 10.1007/s10919-009-0082-1

Panksepp, J., and Watt, D. (2011). Why does depression hurt? Ancestral primary-process separation-distress (PANIC/GRIEF) and diminished brain reward (SEEKING) processes in the genesis of depressive affect. *Psychiatry* 74, 5–13. doi: 10.1521/psyc.2011.74.1.5

Peschard, V., Philippot, P., Joassin, F., and Rossignol, M. (2013). The impact of the stimulus features and task instructions on facial processing in social anxiety: an ERP investigation. *Biol. Psychol.* 93, 88–96. doi: 10.1016/j.biopsycho.2013.01.009

Phan, K. L., Fitzgerald, D. A., Nathan, P. J., and Tancer, M. E. (2006). Association between amygdala hyperactivity to harsh faces and severity of social anxiety in generalized social phobia. *Biol. Psychiatry* 59, 424–429. doi: 10.1016/j.biopsych.2005.08.012

Pitterman, H., and Nowicki, S. (2004). A test of the ability to identify emotion in human standing and sitting postures: the diagnostic analysis of nonverbal accuracy-2 posture test (DANVA2-POS). *Genet. Soc. Gen. Psychol. Monogr.* 130, 146–162. doi: 10.3200/mono.130.2.146-162

Pönkänen, L. M., and Hietanen, J. K. (2012). Eye contact with neutral and smiling faces: effects on autonomic responses and frontal EEG asymmetry. *Front. Hum. Neurosci.* 6:122. doi: 10.3389/fnhum.2012.00122

Poulin, M. J., Holman, E. A., and Buffone, A. (2012). The neurogenetics of nice: receptor genes for oxytocin and vasopressin interact with threat to predict prosocial behavior. *Psychol. Sci.* 23, 446–452. doi: 10.1177/0956797611428471

Quadflieg, S., Mohr, A., Mentzel, H.-J., Miltner, W. H. R., and Straube, T. (2008). Modulation of the neural network involved in the processing of anger prosody: the role of task-relevance and social phobia. *Biol. Psychol.* 78, 129–137. doi: 10.1016/j.biopsycho.2008.01.014

Quadflieg, S., Wendt, B., Mohr, A., Miltner, W. H. R., and Straube, T. (2007). Recognition and evaluation of emotional prosody in individuals with generalized social phobia: a pilot study. *Behav. Res. Ther.* 45, 3096–3103. doi: 10.1016/j.brat.2007.08.003

Quirin, M., Düsing, R., and Kuhl, J. (2013). Implicit affiliation motive predicts correct intuitive judgment. *J. Individ. Differences* 34, 24–31. doi: 10.1027/1614-0001/a000086

Rapee, R. M., and Heimberg, R. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/s0005-7967(97)00022-3

Rapee, R. M., and Lim, L. (1992). Discrepancy between self- and observer ratings of performance in social phobics. *J. Abnorm. Psychol.* 101, 728–731. doi: 10.1037//0021-843x.101.4.728

Rapee, R. M., McCallum, S. L., Melville, L. F., Ravenscroft, H., and Rodney, J. M. (1994). Memory bias in social phobia. *Behav. Res. Ther.* 32, 89–99. doi: 10.1016/0005-7967(94)90087-6

Reed, C. L., Stone, V. E., and McGoldrick, J. E. (2006). "Not just posturing: configural processing of the human body," in *Human Body Perception From the Inside Out: Advances in Visual Cognition*, eds G. Knoblich, I. M. Thornton, M. Grosjean and M. Shiffrar (New York, NY, US: Oxford University Press), 229–258.

Reed, C. L., Stone, V. E., Bozova, S., and Tanaka, J. (2003). The body-inversion effect. *Psychol. Sci.* 14, 302–308. doi: 10.1111/1467-9280.14431

Riem, M. M. E., Bakermans-Kranenburg, M. J., Huffmeijer, R., and van Ijzendoorn, M. H. (2013). Does intranasal oxytocin promote prosocial behavior to an excluded fellow player? A randomized-controlled trial with Cyberball. *Psychoneuroendocrinology* 38, 1418–1425. doi: 10.1016/j.psyneuen.2012.12.023

Rinck, M., and Becker, E. S. (2005). A comparison of attentional biases and memory biases in women with social phobia and major depression. *J. Abnorm. Psychol.* 114, 62–74. doi: 10.1037/0021-843x.114.1.62

Rodebaugh, T. L. (2009). Social phobia and perceived friendship quality. *J. Anxiety Disord.* 23, 872–878. doi: 10.1016/j.janxdis.2009.05.001

Roelofs, K., Putman, P., Schouten, S., Lange, W.-G., Volman, I., and Rinck, M. (2010). Gaze direction differentially affects avoidance tendencies to happy and angry faces in socially anxious individuals. *Behav. Res. Ther.* 48, 290–294. doi: 10.1016/j.brat.2009.11.008

Rowell, T. E. (1974). The concept of social dominance. *Behav. Biol.* 11, 131–154. doi: 10.1016/s0091-6773(74)90289-2

Rule, N. O., Adams, G. R., Ambady, N., and Freeman, J. B. (2012). Perceptions of dominance following glimpses of faces and bodies. *Perception* 41, 687–706. doi: 10.1068/p7023

Safren, S. A., Heimberg, R. G., Horner, K. J., Juster, H. R., Schneier, F. R., and Liebowitz, M. R. (1999). Factor structure of social fears: the liebowitz social anxiety scale. *J. Anxiety Disord.* 13, 253–270. doi: 10.1016/s0887-6185(99)00003-1

Sapolsky, R. M. (2005). The influence of social hierarchy on primate health. *Science* 308, 648–652. doi: 10.1126/science.1106477

Sauter, D. A., and Eimer, M. (2010). Rapid detection of emotion from human vocalizations. *J. Cogn. Neurosci.* 22, 474–481. doi: 10.1162/jocn.2009.21215

Scherer, K. R. (1981). "Vocal indicators of stress," in *Speech Evaluation in Psychiatry*, ed J. K. Darby (New York, NY: Grune & Stratton), 171–187.

Schmitz, J., Scheel, C. N., Rigon, A., Gross, J. J., and Blechert, J. (2012). You don't like me, do you? Enhanced ERP responses to averted eye gaze in social anxiety. *Biol. Psychol.* 91, 263–269. doi: 10.1016/j.biopsycho.2012.07.004

Schneier, F. R., Kent, J. M., Star, A., and Hirsch, J. (2009). Neural circuitry of submissive behavior in social anxiety disorder: a preliminary study of response to direct eye gaze. *Psychiatry Res.* 173, 248–250. doi: 10.1016/j.pscychresns.2008.06.004

Schneier, F. R., Rodebaugh, T. L., Blanco, C., Lewin, H., and Liebowitz, M. R. (2011). Fear and avoidance of eye contact in social anxiety disorder. *Compr. Psychiatry* 52, 81–87. doi: 10.1016/j.comppsych.2010.04.006

Schofield, C. A., Johnson, A. L., Inhoff, A. W., and Coles, M. E. (2012). Social anxiety and difficulty disengaging threat: evidence from eye-tracking. *Cogn. Emot.* 26, 300–311. doi: 10.1080/02699931.2011.602050

Schug, J., Matsumoto, D., Horita, Y., Yamagishi, T., and Bonnet, K. (2010). Emotional expressivity as a signal of cooperation. *Evol. Hum. Behav.* 31, 87–94. doi: 10.1016/j.evolhumbehav.2009.09.006

Schultheiss, O. C., and Wirth, M. M. (2008). "Biopsychological aspects of motivation," in *Motivation and Action*, 2nd Edn., ed J. H. H. Heckhausen (New York, NY, US: Cambridge University Press), 247–271.

Sellers, J. G., Mehl, M. R., and Josephs, R. A. (2007). Hormones and personality: testosterone as a marker of individual differences. *J. Res. Pers.* 41, 126–138. doi: 10.1016/j.jrp.2006.02.004

Shariff, A. F., and Tracy, J. L. (2009). Knowing who's boss: implicit perceptions of status from the nonverbal expression of pride. *Emotion* 9, 631–639. doi: 10.1037/a0017089

Shaver, P. R., Segev, M., and Mikulincer, M. (2011). "A behavioral systems perspective on power and aggression," in *Human aggression and Violence: Causes, Manifestations and Consequences*, eds P. R. Shaver and M. Mikulincer (Washington, DC, US: American Psychological Association), 71–87.

Siegman, A. W. (1987). "The telltale voice: nonverbal messages of verbal communication," in *Nonverbal Behavior and Communication*, eds A. W. Siegman and S. Feldstein (NJ: Hillsdale), 351–433.

Silk, J. B. (2007). Social components of fitness in primate groups. *Science* 317, 1347–1351. doi: 10.1126/science.1140734

Sloman, K., and Armstrong, J. D. (2002). Physiological effects of dominance hierarchies: laboratory artefacts or natural phenomena? *J. Fish Biol.* 61, 1–23. doi: 10.1111/j.1095-8649.2002.tb01733.x

Spokas, M., Luterek, J. A., and Heimberg, R. G. (2009). Social anxiety and emotional suppression: the mediating role of beliefs. *J. Behav. Ther. Exp. Psychiatry* 40, 283–291. doi: 10.1016/j.jbtep.2008.12.004

Stanton, S. J., Hall, J. L., and Schultheiss, O. C. (2010). "Properties of motive-specific incentives," in *Implicit Motives*, eds O. C. Schultheiss and J. C. Brunstein (New York: Oxford University Press), 245–278.

Stanton, S. J., and Schultheiss, O. C. (2007). Basal and dynamic relationships between implicit power motivation and estradiol in women. *Horm. Behav.* 52, 571–580. doi: 10.1016/j.yhbeh.2007.07.002

Staugaard, S. R. (2010). Threatening faces and social anxiety: a literature review. *Clin. Psychol. Rev.* 30, 669–690. doi: 10.1016/j.cpr.2010.05.001

Stein, M. B. (2002). Increased amygdala activation to angry and contemptuous faces in generalized social phobia. *Arch. Gen. Psychiatry* 59, 1027–1034. doi: 10.1001/archpsyc.59.11.1027

Stein, M. B., Goldin, P. R., Sareen, J., Zorrilla, L. T. E., and Brown, G. G. (2002). Increased amygdala activation to angry and contemptuous faces in generalized social phobia. *Arch. Gen. Psychiatry* 59, 1027–1034. doi: 10.1001/archpsyc.59.11.1027

Stein, D. J., Kasper, S., Andersen, E. W., Nil, R., and Lader, M. (2004). Escitalopram in the treatment of social anxiety disorder: analysis of efficacy for different clinical subgroups and symptom dimensions. *Depress. Anxiety* 20, 175–181. doi: 10.1002/da.20043

Stein, M. B., and Kean, Y. M. (2000). Disability and quality of life in social phobia: epidemiologic findings. *Am. J. Psychiatry* 157, 1606–1613. doi: 10.1176/appi.ajp.157.10.1606

Stel, M., Dijk, W. W., Smith, P. K., and Djalal, F. M. (2012). Lowering the pitch of your voice makes you feel more powerful and think more abstractly. *Soc. Psychol. Personal. Sci.* 3, 497–502. doi: 10.1177/1948550611427610

Stel, M., van Baaren, R. B., Blascovich, J., van Dijk, E., McCall, C., Pollmann, M. M. H., et al. (2010). Effects of a priori liking on the elicitation of mimicry. *Exp. Psychol.* 57, 412–418. doi: 10.1027/1618-3169/a000050

Stel, M., and van Knippenberg, A. (2008). The role of facial mimicry in the recognition of affect. *Psychol. Sci.* 19, 984–985. doi: 10.1111/j.1467-9280.2008.02188.x

Stevens, S., Hofmann, M., Kiko, S., Mall, A. K., Steil, R., Bohus, M., et al. (2010). What determines observer-rated social performance in individuals with social anxiety disorder? *J. Anxiety Disord.* 24, 830–836. doi: 10.1016/j.janxdis.2010.06.005

Stienen, B. M. C., and de Gelder, B. (2011). Fear detection and visual awareness in perceiving bodily expressions. *Emotion* 11, 1182–1189. doi: 10.1037/a0024032

Straube, T., Mentzel, H.-J., and Miltner, W. H. R. (2005). Common and distinct brain activation to threat and safety signals in social phobia. *Neuropsychobiology* 52, 163–168. doi: 10.1159/000087987

Taylor, S. E. (2006). Tend and befriend: biobehavioral bases of affiliation under stress. *Curr. Dir. Psychol. Sci.* 15, 273–277. doi: 10.1111/j.1467-8721.2006.00451.x

Taylor, C. T., and Alden, L. E. (2011). To see ourselves as others see us: an experimental integration of the intra and interpersonal consequences of self-protection in social anxiety disorder. *J. Abnorm. Psychol.* 120, 129–141. doi: 10.1037/a0022127

Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., and Updegraff, J. A. (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychol. Rev.* 107, 411–429. doi: 10.1037/0033-295x.107.3.411

Terburg, D., Aarts, H., and van Honk, J. (2012). Memory and attention for social threat: anxious hypercoding-avoidance and submissive gaze aversion. *Emotion* 12, 666–672. doi: 10.1037/a0027201

Terburg, D., and van Honk, J. (2013). Approach-avoidance versus dominance-submissiveness: a multilevel neural framework on how testosterone promotes social status. *Emot. Rev.* 5, 296–302. doi: 10.1177/1754073913477510

Thomsen, L., Frankenhuis, W. E., Ingold-Smith, M., and Carey, S. (2011). Big and mighty: preverbal infants mentally represent social dominance. *Science* 331, 477–480. doi: 10.1126/science.1199198

Tiedens, L. Z., and Fragale, A. R. (2003). Power moves: complementarity in dominant and submissive nonverbal behavior. *J. Pers. Soc. Psychol.* 84, 558–568. doi: 10.1037/0022-3514.84.3.558

Tinlin, R. M., Watkins, C. D., Welling, L. L. M., DeBruine, L. M., Al-Dujaili, E. A. S., and Jones, B. C. (2013). Perceived facial adiposity conveys information about women's health. *Br. J. Psychol.* 104, 235–248. doi: 10.1111/j.2044-8295.2012.02117.x

Todorov, A., Dotsch, R., Porter, J. M., Oosterhof, N. N., and Falvello, V. B. (2013). Validation of data-driven computational models of social perception of faces. *Emotion* 13, 724–738. doi: 10.1037/a0032335

Todorov, A., Pakrashi, M., and Oosterhof, N. N. (2009). Evaluating faces on trustworthiness after minimal time exposure. *Soc. Cogn.* 27, 813–833. doi: 10.1521/soco.2009.27.6.813

Tracy, J. L., and Robins, R. W. (2004). Show your pride: evidence for a discrete emotion expression. *Psychol. Sci.* 15, 194–197. doi: 10.1111/j.0956-7976.2004.01503008.x

Tracy, J. L., and Robins, R. W. (2007). The prototypical pride expression: development of a nonverbal behavior coding system. *Emotion* 7, 789–801. doi: 10.1037/1528-3542.7.4.789

Tracy, J. L., Shariff, A. F., Zhao, W., and Henrich, J. (2013). Cross-cultural evidence that the nonverbal expression of pride is an automatic status signal. *J. Exp. Psychol. Gen.* 142, 163–180. doi: 10.1037/a0028412

Van den Stock, J., Righart, R., and de Gelder, B. (2007). Body expressions influence recognition of emotions in the face and voice. *Emotion* 7, 487–494. doi: 10.1037/1528-3542.7.3.487

Veit, R., Flor, H., Erb, M., Hermann, C., Lotze, M., Grodd, W., et al. (2002). Brain circuits involved in emotional learning in antisocial behavior and social phobia in humans. *Neurosci. Lett.* 328, 233–236. doi: 10.1016/s0304-3940(02)00519-0

Voncken, M. J., and Bögels, S. M. (2008). Social performance deficits in social anxiety disorder: reality during conversation and biased perception during speech. *J. Anxiety Disord.* 22, 1384–1392. doi: 10.1016/j.janxdis.2008.02.001

Vrana, S. R., and Gross, D. (2004). Reactions to facial expressions: effects of social context and speech anxiety on responses to neutral, anger and joy expressions. *Biol. Psychol.* 66, 63–78. doi: 10.1016/j.biopsycho.2003.07.004

Vrijsen, J. N., Lange, W.-G., Becker, E. S., and Rinck, M. (2010). Socially anxious individuals lack unintentional mimicry. *Behav. Res. Ther.* 48, 561–564. doi: 10.1016/j.brat.2010.02.004

Walker, A. S., Nowicki, S., Jones, J., and Heimann, L. (2011). Errors in identifying and expressing emotion in facial expressions, voices and postures unique to social anxiety. *J. Genet. Psychol.* 172, 293–301. doi: 10.1080/00221325.2010.535224

Wallace, S. T., and Alden, L. E. (1997). Social phobia and positive social events: the price of success. *J. Abnorm. Psychol.* 106, 416–424. doi: 10.1037/0021-843x.106.3.416

Weeks, J., Heimberg, R. G., and Heuer, R. (2011). Exploring the role of behavioral submissiveness in social anxiety. *Soc. Clin. Psychol.* 30, 217–249. doi: 10.1521/jscp.2011.30.3.217

Weeks, J. W., Lee, C.-Y., Reilly, A. R., Howell, A. N., France, C., Kowalsky, J. M., et al. (2012). "The sound of fear": assessing vocal fundamental frequency as a physiological indicator of social anxiety disorder. *J. Anxiety Disord.* 26, 811–822. doi: 10.1016/j.janxdis.2012.07.005

Weisfeld, G. E., and Beresford, J. M. (1982). Erectness of posture as an indicator of dominance or success in humans. *Motiv. Emot.* 6, 113–131. doi: 10.1007/bf00992459

Weisman, O., Aderka, I. M., Marom, S., Hermesh, H., and Gilboa-Schechtman, E. (2011). Social rank and affiliation in social anxiety disorder. *Behav. Res. Ther.* 49, 399–405. doi: 10.1016/j.brat.2011.03.010

West-Eberhard, M. J. (1979). Sexual selection, social competition and evolution. *Proc. Am. Philos. Soc.* 123, 222–234.

Wieser, M. J., McTeague, L. M., and Keil, A. (2011). Sustained preferential processing of social threat cues: bias without competition? *J. Cogn. Neurosci.* 23, 1973–1986. doi: 10.1162/jocn.2010.21566

Wieser, M. J., Pauli, P., Alpers, G. W., and Mühlberger, A. (2009). Is eye to eye contact really threatening and avoided in social anxiety?–An eye-tracking and psychophysiology study. *J. Anxiety Disord.* 23, 93–103. doi: 10.1016/j.janxdis.2008.04.004

Wieser, M. J., Pauli, P., Grosseibl, M., Molzow, I., and Mühlberger, A. (2010). Virtual social interactions in social anxiety–the impact of sex, gaze and interpersonal distance. *Cyberpsychol. Behav. Soc. Netw.* 13, 547–554. doi: 10.1089/cyber.2009.0432

Wirth, J. H., Sacco, D. F., Hugenberg, K., and Williams, K. D. (2010). Eye gaze as relational evaluation: averted eye gaze leads to feelings of ostracism and relational devaluation. *Pers. Soc. Psychol. Bull.* 36, 869–882. doi: 10.1177/0146167210370032

Wolff, S. E., and Puts, D. A. (2010). Vocal masculinity is a robust dominance signal in men. *Behav. Ecol. Sociobiol.* 64, 1673–1683. doi: 10.1007/s00265-010-0981-5

Yoon, K. L., Fitzgerald, D. A., Angstadt, M., McCarron, R. A., and Phan, K. L. (2007). Amygdala reactivity to emotional faces at high and low intensity in generalized social phobia: a 4-Tesla functional MRI study. *Psychiatry Res.* 154, 93–98. doi: 10.1016/j.pscychresns.2006.05.004

Young, T. J., and French, L. A. (1998). Heights of U.S. Presidents: a trend analysis for 1948-1996. *Percept. Mot. Skills.* 87, 321–322. doi: 10.2466/pms.1998.87.1.321

Zitek, E. M., and Tiedens, L. Z. (2012). The fluency of social hierarchy: the ease with which hierarchical relationships are seen, remembered, learned and liked. *J. Pers. Soc. Psychol.* 102, 98–115. doi: 10.1037/a0025345

Zuckerman, M., and Driver, R. E. (1989). What sounds beautiful is good: the vocal attractiveness stereotype. *J. Nonverbal Behav.* 13, 67–82. doi: 10.1007/bf00990791

Zuroff, D. C., Fournier, M. A., Patall, E. A., and Leybman, M. J. (2010). Steps toward an evolutionary personality psychology: individual differences in the social rank domain. *Can. Psychol.* 51, 58–66. doi: 10.1037/a0018472

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Towards a cross-modal perspective of emotional perception in social anxiety: review and future directions

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The excessive fear of being negatively evaluated constitutes a central component of social anxiety (SA). Models posit that selective attention to threat and biased interpretations of ambiguous stimuli contribute to the maintenance of this psychopathology. There is strong support for the existence of processing biases but most of the available evidence comes from face research. Emotions are, however, not only conveyed through facial cues, but also through other channels, such as vocal and postural cues. These non-facial cues have yet received much less attention. We therefore plead for a cross-modal investigation of biases in SA. We argue that the inclusion of new modalities may be an efficient research tool to (1) address the specificity or generalizability of these biases; (2) offer an insight into the potential influence of SA on cross-modal processes; (3) operationalize emotional ambiguity by manipulating cross-modal emotional congruency; (4) inform the debate about the role of top-down and bottom-up factors in biasing attention; and (5) probe the cross-modal generalizability of cognitive training. Theoretical and clinical implications as well as potential fruitful avenues for research are discussed.

Keywords: cross-modality, emotion, social anxiety, face, voice

INTRODUCTION

Influential models of social anxiety (SA) implicate cognitive biases as maintaining factors (Clark and Wells, 1995; Rapee and Heimberg, 1997). The existing evidence concerning biases in SA has largely relied on faces (for a review, Staugaard, 2010). Particularly, there is strong support for attentional biases (AB) towards facial stimuli among high socially anxious (HSA) individuals. While some studies indicated a facilitated attention to threatening faces (Mogg et al., 2004; Pishyar et al., 2004), others demonstrated difficulties in disengaging attention from these cues (Buckner et al., 2010; Schofield et al., 2012). Significant efforts have also been directed at understanding the effect of SA on the interpretation of faces, but have yielded mixed results, possibly due to methodological differences in dependent variables, stimuli and tasks. While several studies indicate that SA modulates the interpretation of emotional facial expressions (e.g., ratings of the emotional cost for interacting with the expressor: Schofield et al., 2007; Douilliez et al., 2012), other studies did not find any differences between HSA and controls (e.g., disapproval ratings: Douilliez and Philippot, 2003; decoding accuracy: Philippot and Douilliez, 2005).

To date, evidence linking SA to cognitive biases provided much information about how HSA individuals process faces. However, conclusions from these studies are limited to the processing of faces. Further, some questions are still controversial, in part due to the inherent methodological limitations of face research. Social interactions mobilize multiple channels, including speech style, facial expressions, postures, gestures, and tone of voice. Focusing research solely on faces raises the risk of overlooking other channels that are heavily implicated in social interactions. We argue that the investigation of SA-related biases needs to be extended to a multi-modal approach (as also suggested by Gilboa-Schechtman and Shachar-Lavie, 2013; Schulz et al., 2013), including the modalities that are most important in social interaction: vision and hearing. The use of cross-modal paradigms will allow the re-evaluation of studies using uni-modal stimuli, which could underestimate the cognitive biases present in real life. To support this statement, we developed several arguments based on empirical evidence, with the aim of identifying useful avenues for future research.

ARGUMENTS

INCLUDING EMOTIONAL PROSODY TO PROBE THE GENERALIZABILITY OF COGNITIVE BIASES IN SOCIAL ANXIETY

Emotional prosody refers to all changes in acoustic parameters, such as intonation, amplitude, envelope, tempo, rhythm and voice quality during emotional episodes (Grandjean et al., 2006). It is a powerful communication tool transmitting paralinguistic information, and notably the speaker's emotional state (Belin et al., 2004). Research that neglects the latter channel ignores crucial information for interpersonal interactions. To document its relevance, we will review research on the modulation of attention and emotional judgments by prosody.

Selective attention to emotional prosody

Efficient detection of salient or goal-relevant stimuli is essential to adjust behaviors accordingly. Given the limited processing capacity of our brain, mechanisms of attention play a critical role in selecting most important information from the myriad of sensory inputs. In the competition for processing resources, emotions have been shown to modulate attention (Vuilleumier et al., 2004; Vuilleumier, 2005). To date, the effect of emotional prosody on attention has been mostly assessed during dichotic listening or during the variation of feature-based attention.

The dichotic-listening technique is an attentional filtering task that assesses the ability to suppress or ignore distractors co-occurring with targets. Dichotic-listening investigations typically involve the simultaneous presentation of lateralized male and female voices with identical or different emotional prosody. Participants are requested to focus their attention on one ear and to determine the gender of the speaker on the attended ear. Recently, Aue et al. (2011) reported that, compared to neutral prosody, angry prosody attracts attention and induces behavioral and physiological changes (e.g., increased forehead temperature) with or without voluntary attention. Moreover, neuroimaging studies indicated greater activation for angry relative to neutral prosody in the superior temporal sulcus (Grandjean et al., 2005; Sander et al., 2005) and the amygdala (Sander et al., 2005) irrespective of the focus of attention. These findings suggest that threatening voices might be processed automatically by specific brain regions (but see Mothes-Lasch et al., 2011).

In addition to dichotic-listening methods, several studies (Quadflieg et al., 2008; Ethofer et al., 2009) investigated whether brain responses to angry compared to neutral prosody are modulated by variations in feature-based auditory attention. For example, Quadflieg et al. (2008) examined brain responses to neutral and angry voices while control and HSA subjects judged either the emotion or the gender of the voice. This study confirmed the findings of Sander et al. (2005) showing stronger activation for angry than neutral prosody in amygdala regardless of the task and in orbitofrontal cortex (OFC) during task-relevant as compared to task-irrelevant emotional prosody processing. Additionally, their results indicated that compared to controls, HSA individuals exhibit stronger right OFC response to angry versus neutral prosody regardless of the focus of attention. These findings suggest that the OFC might be implicated in biased processing of threatening prosody in SA.

To conclude, few studies have explored the implicit and explicit processing of emotional prosody via uni-modal attentional distraction from emotion. The lack of studies examining attention to prosodic information in the general population as well as in socially anxious samples is surprising, since the exploration of these processes could contribute to new insights into the attentional processing of emotional information. The above mentioned paradigms offer an interesting opportunity to provide evidence from the auditory modality that might be congruent or incongruent with the evidence accumulated in the visual domain.

Interpretation of emotional prosody

Other studies have focused on the interpretation of affective signals conveyed by faces or voices. These abilities have been increasingly studied in several psychopathologies, including alcohol-dependence (Maurage et al., 2009; Kornreich et al., 2013), depression (Naranjo et al., 2011) and bipolar disorder (Van Rheenen and Rossell, 2013).

Despite this growing interest, we found only one study (Quadflieg et al., 2007) that probed the presence of biases in the interpretation of emotional prosody in SA. Findings indicated that compared to controls, HSA participants present higher correct identification rates for fearful and sad prosody than controls, but conversely show impaired performances for happy prosody. Surprisingly, there were no differences between groups for neutral, anger and disgust prosody, as well as with regard to valence and arousal ratings for any prosody. These findings suggest that HSA individuals interpret prosody in a different manner than low socially anxious (LSA) individuals. However, it should be noted that this observation is at odds with theoretical predictions of a threat-specific bias, since fearful and sad expressions do not specifically indicate a social threat as would angry expressions do, thereby highlighting the importance of further investigations.

Summary

The lack of studies on emotional prosody in SA is problematic, since a threatening voice is a clear sign of danger and therefore a good candidate for capturing the attention of HSA individuals and eliciting biased interpretations. The study of emotional prosody constitutes a promising tool to investigate the cognitive biases in SA more completely. Presently, it is unclear whether these biases, which are repeatedly described in SA for visual processing, are similar in the auditory channel. Yet, the few existing data suggest some particularities in the processing of emotional prosody by HSA individuals. In addition to emotional prosody, other affective stimuli could be useful to probe the generalizability of cognitive biases in SA, notably body language (for an illustration in depression see Loi et al., 2013).

PROVIDING INSIGHTS ABOUT THE POTENTIAL INFLUENCE OF SOCIAL ANXIETY ON THE INTERACTIONS BETWEEN MODALITIES

Audio-visual integration

A specific line of research addresses the ability of humans to integrate co-occurring sources of facial and vocal affective information. In natural environment, humans are immersed in a stream of stimulations from multiple modalities. The ability to integrate these multimodal inputs allows for an unified and coherent representation of the world and for taking advantage of non-redundant and complementary information from a single modality (Ernst and Bülthoff, 2004). The multimodal integration of affective facial and vocal expressions has led to a growing interest in the literature (for a review, Campanella and Belin, 2007). It has been demonstrated that congruency in the facial and vocal expression of emotion facilitates their identification compared to an uni-modal (i.e., face or voice presented in isolation) source of information (e.g., Collignon et al., 2008). Interestingly, integrative processes have been shown to be altered during the emotional perception of facial and vocal expressions in psychopathological populations, such as in alcohol-dependent subjects (Maurage et al., 2007, 2008, 2013). Specifically, alcohol-dependent individuals do not only suffer from a deficit in decoding facial and vocal expressions, but they also present a specific deficit in integrating messages conveyed by these two modalities. Hence, their resulting impairment is not just the sum of impairments in each modality, but it is further aggravated by a difficulty in integrating these modalities.

To our knowledge, no study has investigated the effect of SA on the ability to decode emotions in audio-visual modality, and the possible deficit in integrating these two modalities. This issue is important, as it would suggest that the total deficit in emotional information processing by HSA individuals would not be the addition of the deficits in each modality, but would be even more important, given the over-added integration deficit. Hence, the closer a paradigm would be to a real-life multi-sensory situation, the more pronounced might be the biases. Consequently, earlier uni-modal studies might have underestimated the extent of these biases.

Cross-modal attention

A second line of research has investigated how signals from different modalities influence each other in capturing attention. It has been shown that emotional prosody can serve as an exogenous cue to orient attention towards relevant visual events. Using a cross-modal adaptation of the dot-probe task, Brosch et al. (2008) showed decreased response times to non-emotional visual targets preceded by angry prosody compared to targets preceded by neutral prosody. Brosch et al. (2009) replicated and extended these behavioral findings by showing an amplification of the P1 (an electrophysiological component indexing early visual processing) for visual targets occurring at the spatial location of angry as compared to neutral prosody. These results suggest that emotional attention can operate across modalities because auditory stimuli can enhance early visual processing stages.

Several studies similarly demonstrated that emotional stimuli in one modality influence the processing of emotional information in another modality. For example, emotional prosody can facilitate attention to emotionally congruent facial expressions in visual search (Paulmann et al., 2012; Rigoulot and Pell, 2012) and in cross-modal priming tasks (Pell, 2005a,b; Paulmann and Pell, 2010). Other studies revealed that the judgment of emotional prosody is biased by a concurrent emotional face despite the instruction to ignore this channel (de Gelder and Vroomen, 2000; Vroomen et al., 2001). The reverse effect has also been observed, showing that emotional prosody biases the judgment of the emotion expressed in the face (de Gelder and Vroomen, 2000). These studies suggest that audio-visual integration of emotional signals may be an automatic and mandatory process, as this effect seems to arise independently of voluntary attentional factors (de Gelder and Vroomen, 2000; Vroomen et al., 2001) and of the awareness of the face (de Gelder et al., 2002).

Based on this line of research, one would want to investigate whether such automatic control of attention across modalities is modulated by SA. Such research could help identifying the origin of the SA biases on the top-down—bottom-up continuum. One could also hypothesize that HSA individuals could be more influenced than LSA individuals by cross-modal interference, if that interference can be interpreted as a social threat. These kind of studies need still to be conducted. The results obtained in healthy populations also raise the question of how conflicting emotional information is processed by HSA individuals. This topic will be developed in the next section.

MANIPULATING THE CROSS-MODAL EMOTIONAL CONGRUENCY AS A TOOL TO OPERATIONALIZE AMBIGUITY

In the environment, we frequently encounter conflicting situations in which two modalities convey incongruent information (De Gelder and Bertelson, 2003). As mentioned, the categorization of emotional stimuli is affected by incongruent information provided by the second channel in cross-modal situations. Few studies have investigated such cross-modal incongruence effects among psychopathological populations. Some studies have described disturbed cross-modal integration of emotional faces and voices in schizophrenia (de Gelder et al., 2005; de Jong et al., 2009). However, no study has explored the effect of SA on the ability to decode incongruent emotional faces and voices. Yet, in real-life conditions, conversational partner often do not provide direct unambiguous feedback about their approval or disapproval. Such ambiguity leaves room for the socially anxious' tendency to interpret responses as signs of negative evaluation. Recently, Koizumi et al. (2011) used a cross-modal bias paradigm (Bertelson and De Gelder, 2004) that included emotionally congruent or incongruent voice-face pairs. Participants had to decode the emotion displayed in one of the two channels (e.g., face) while ignoring the other (e.g., voice). Results indicate that individuals with heightened trait anxiety were likely to interpret the stimuli more negatively, putting more weight on the to-be-ignored angry faces or voices. As a consequence, manipulating emotional congruency across modalities can be a powerful way to examine the impact of ambiguity on the judgment of social information and to renew the exploration of biases in SA.

INFORMING DEBATE ABOUT THE ROLE OF TOP-DOWN AND BOTTOM-UP FACTORS IN BIASING ATTENTION TO THREAT

Different models of anxiety have questioned the balance between bottom-up and top-down attention to explain cognitive biases. First, Bishop (2007) proposes that anxiety leads to AB by amplifying amygdala responsiveness to threat and/or by impairing the recruitment of top-down attention control, particularly under conditions of low perceptual load. In the same vein, the attentional control theory (Eysenck et al., 2007) and recent developments (e.g., Berggren and Derakshan, 2013; Berggren et al., 2013) suggest that individuals reporting high trait anxiety have to engage a greater amount of attentional control under low cognitive load (thereby reducing efficiency) to attain the level of performance achieved by low-anxious individuals. However, high cognitive load can disrupt performance in tasks requiring attentional control particularly in high anxious individuals. Finally, Hirsch and Mathews (2012) propose that high levels of anxiety are characterized by an imbalance between (weak) top/down and (strong) bottom/up attentional processes, the latter being automatically fueled by threat.

While behavioral studies demonstrated a rapid orientation towards threatening faces (Mogg et al., 2004; Pishyar et al., 2004), neuroimaging studies showed increased amygdala response, exaggerated negative emotion reactivity, and reduced cognitive regulation-related neural activation to faces in SA (Goldin et al., 2009; Ball et al., 2012). An increased vigilance for faces, indexed by enhanced P1, is also well documented in SA

(Rossignol et al., 2012; Peschard et al., 2013). Nevertheless, most of this research is limited to visual stimuli and therefore prevents us from drawing firm conclusions about the implication of top-down and bottom-up factors in the generation of cognitive biases. Investigating the presence of biases across modalities offers an interesting paradigm to provide an insight into the contribution of top-down and bottom-up influences. Indeed, if a bias is generated at an early perceptual level, and thus nested in a specific modality, it is unlikely that the same bias would be reproduced in all other modalities. Consequently, the absence of generalization of a cognitive bias across modalities would support the notion that this bias is yielded by bottom-up processes, whereas its presence across modalities would rather support the notion of a top-down influence. As far as we know, no study has yet explored these integrative processes in SA, thus stressing the need to initiate this field of research.

THE CROSS-MODAL GENERALIZABILITY OF COGNITIVE TRAINING

Recent studies have shown that training HSA individuals to attend to non-threatening stimuli reduces AB, which in turn diminishes anxiety (Amir et al., 2008; Heeren et al., 2012b). It has also been demonstrated that inducing AB for threat induces anxiety (Heeren et al., 2012a). These findings support the proposal that AB to threat play a causal role in the maintenance and the development of SA. However, previous research has left unaddressed several important issues both at the fundamental and clinical level. First, there is a need to obtain a more ecological and complete AB evaluation before AB training. It should be established whether similar AB are present across modalities (as posed by theoretical models) or whether they are proper to a specific modality, hence suggesting retraining in that specific modality. Moreover if research findings show that AB appear across modalities, a crucial question would be whether training in one modality would transfer its effects to other modalities. This cross-modal perspective can offer an interesting paradigm to disentangle top-down and bottom-up determinations of AB. Finally, this perspective could lead to innovative AB training based on the combination of different modalities.

CONCLUSION

We developed several arguments pleading for a cross-modal perspective in the investigation of biases in SA. In addition to the gain of a more complete and ecological picture of cognitive biases, a cross-modal perspective opens up new possibilities for understanding fundamental processes underlying biases in SA. This perspective might help to determine the stage of processing at which these biases occur. In this contribution, we mainly focused on auditory and visual modalities. However, signals from other modalities, like olfaction, could also influence information processing and should thus be considered in psychopathological research (Maurage et al., 2014). Recently, Adolph et al. (2013) have reported that HSA individuals might be particularly sensitive to chemosensory contextual social information during the processing of anxious facial expressions. This outlines the usefulness to exploring cross-modal processing in order to precisely describe cognitive biases in SA.

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REFERENCES

Adolph, D., Meister, L., and Pause, B. M. (2013). Context counts! social anxiety modulates the processing of fearful faces in the context of chemosensory anxiety signals. *Front. Hum. Neurosci.* 7:283. doi: 10.3389/fnhum.2013.00283

Amir, N., Weber, G., Beard, C., Bomyea, J., and Taylor, C. T. (2008). The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals. *J. Abnorm. Psychol.* 117, 860–868. doi: 10.1037/a0013445

Aue, T., Cuny, C., Sander, D., and Grandjean, D. (2011). Peripheral responses to attended and unattended angry prosody: a dichotic listening paradigm. *Psychophysiology* 48, 385–392. doi: 10.1111/j.1469-8986.2010.01064.x

Ball, T. M., Sullivan, S., Flagan, T., Hitchcock, C. A., Simmons, A., Paulus, M. P., et al. (2012). Selective effects of social anxiety, anxiety sensitivity, and negative affectivity on the neural bases of emotional face processing. *Neuroimage* 59, 1879–1887. doi: 10.1016/j.neuroimage.2011.08.074

Belin, P., Fecteau, S., and Bedard, C. (2004). Thinking the voice: neural correlates of voice perception. *Trends Cogn. Sci.* 8, 129–135. doi: 10.1016/j.tics.2004.01.008

Berggren, N., and Derakshan, N. (2013). Attentional control deficits in trait anxiety: why you see them and why you don't. *Biol. Psychol.* 92, 440–446. doi: 10.1016/j.biopsycho.2012.03.007

Berggren, N., Richards, A., Taylor, J., and Derakshan, N. (2013). Affective attention under cognitive load: reduced emotional biases but emergent anxiety-related costs to inhibitory control. *Front. Hum. Neurosci.* 7:188. doi: 10.3389/fnhum.2013.00188

Bertelson, P., and De Gelder, B. (2004). "The psychology of multimodal perception," in *CrossmoDal Space and Crossmodal Attention*, ed J. Driver (Oxford: Oxford University Press), 151–177.

Bishop, S. J. (2007). Neurocognitive mechanisms of anxiety: an integrative account. *Trends Cogn. Sci.* 11, 307–316. doi: 10.1016/j.tics.2007.05.008

Brosch, T., Grandjean, D., Sander, D., and Scherer, K. R. (2008). Behold the voice of wrath: cross-modal modulation of visual attention by anger prosody. *Cognition* 106, 1497–1503. doi: 10.1016/j.cognition.2007.05.011

Brosch, T., Grandjean, D., Sander, D., and Scherer, K. R. (2009). Cross-modal emotional attention: emotional voices modulate early stages of visual processing. *J. Cogn. Neurosci.* 21, 1670–1679. doi: 10.1162/jocn.2009.21110

Buckner, J. D., Maner, J. K., and Schmidt, N. B. (2010). Difficulty disengaging attention from social threat in social anxiety. *Cognit. Ther. Res.* 34, 99–105. doi: 10.1007/s10608-008-9205-y

Campanella, S., and Belin, P. (2007). Integrating face and voice in person perception. *Trends. Cogn. Sci.* 11, 535–543. doi: 10.1016/j.tics.2007.10.001

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Diagnosis, Assessment and Treatment*, eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope and R. Schneider (New York: Guilford), 69–93.

Collignon, O., Girard, S., Gosselin, F., Roy, S., Saint-Amour, D., Lassonde, M., et al. (2008). Audio-visual integration of emotion expression. *Brain Res.* 1242, 126–135. doi: 10.1016/j.brainres.2008.04.023

De Gelder, B., and Bertelson, P. (2003). Multisensory integration, perception and ecological validity. *Trends Cogn. Sci.* 7, 460–467. doi: 10.1016/j.tics.2003.08.014

de Jong, J. J., Hodiamont, P. P., Van den Stock, J., and de Gelder, B. (2009). Audiovisual emotion recognition in schizophrenia: reduced integration of facial and vocal affect. *Schizophr. Res.* 107, 286–293. doi: 10.1016/j.schres.2008.10.001

de Gelder, B., Pourtois, G., and Weiskrantz, L. (2002). Fear recognition in the voice is modulated by unconsciously recognized facial expressions but not by unconsciously recognized affective pictures. *Proc. Natl. Acad. Sci. U S A* 99, 4121–4126. doi: 10.1073/pnas.062018499

de Gelder, B., and Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cogn. Emot.* 14, 289–311. doi: 10.1080/026999300378824

de Gelder, B., Vroomen, J., De Jong, S. J., Masthoff, E. D., Trompenaars, F. J., and Hodiamont, P. (2005). Multisensory integration of emotional faces and voices in schizophrenics. *Schizophr. Res.* 72, 195–203. doi: 10.1016/j.schres.2004.02.013

Douilliez, C., and Philippot, P. (2003). Biais dans l'évaluation volontaire de stimuli verbaux et non-verbaux: effet de l'anxiété sociale. *Francophone J. Clin. Behav. Cogn.* 8, 12–18.

Douilliez, C., Yzerbyt, V., Gilboa-Schechtman, E., and Philippot, P. (2012). Social anxiety biases the evaluation of facial displays: evidence from single face and multi-facial stimuli. *Cogn. Emot.* 26, 1107–1115. doi: 10.1080/02699931.2011.632494

Ernst, M. O., and Bülthoff, H. H. (2004). Merging the senses into a robust percept. *Trends Cogn. Sci.* 8, 162–169. doi: 10.1016/j.tics.2004.02.002

Ethofer, T., Kreifelts, B., Wiethoff, S., Wolf, J., Grodd, W., Vuilleumier, P., et al. (2009). Differential influences of emotion, task and novelty on brain regions underlying the processing of speech melody. *J. Cogn. Neurosci.* 21, 1255–1268. doi: 10.1162/jocn.2009.21099

Eysenck, M. W., Derakshan, N., Santos, R., and Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion* 7, 336–353. doi: 10.1037/1528-3542.7.2.336

Gilboa-Schechtman, E., and Shachar-Lavie, I. (2013). More than a face: a unified theoretical perspective on nonverbal social cue processing in social anxiety. *Front. Hum. Neurosci.* 7:904. doi: 10.3389/fnhum.2013.00904

Goldin, P. R., Manber, T., Hakimi, S., Canli, T., and Gross, J. J. (2009). Neural bases of social anxiety disorder: emotional reactivity and cognitive regulation during social and physical threat. *Arch. Gen. Psychiatry* 66, 170–180. doi: 10.1001/archgenpsychiatry.2008.525

Grandjean, D., Banziger, T., and Scherer, K. R. (2006). Intonation as an interface between language and affect. *Prog. Brain Res.* 156, 235–247. doi: 10.1016/s0079-6123(06)56012-1

Grandjean, D., Sander, D., Pourtois, G., Schwartz, S., Seghier, M. L., Scherer, K. R., et al. (2005). The voices of wrath: brain responses to angry prosody in meaningless speech. *Nat. Neurosci.* 8, 145–146. doi: 10.1038/nn1392

Heeren, A., Peschard, V., and Philippot, P. (2012a). The causal role of attentional bias for threat cues in social anxiety: a test on a cyber-ostracism task. *Cognit. Ther. Res.* 36, 512–521. doi: 10.1007/s10608-011-9394-7

Heeren, A., Reese, H. E., McNally, R. J., and Philippot, P. (2012b). Attention training toward and away from threat in social phobia: effects on subjective, behavioral and physiological measures of anxiety. *Behav. Res. Ther.* 50, 30–39. doi: 10.1016/j.brat.2011.10.005

Hirsch, C. R., and Mathews, A. (2012). A cognitive model of pathological worry. *Behav. Res. Ther.* 50, 636–646. doi: 10.1016/j.brat.2012.06.007

Koizumi, A., Tanaka, A., Imai, H., Hiramatsu, S., Hiramoto, E., Sato, T., et al. (2011). The effects of anxiety on the interpretation of emotion in the face-voice pairs. *Exp. Brain Res.* 213, 275–282. doi: 10.1007/s00221-011-2668-1

Kornreich, C., Brevers, D., Canivet, D., Ermer, E., Naranjo, C., Constant, E., et al. (2013). Impaired processing of emotion in music, faces and voices supports a generalized emotional decoding deficit in alcoholism. *Addiction* 108, 80–88. doi: 10.1111/j.1360-0443.2012.03995.x

Loi, F., Vaidya, J. G., and Paradiso, S. (2013). Recognition of emotion from body language among patients with unipolar depression. *Psychiatry Res.* 209, 40–49. doi: 10.1016/j.psychres.2013.03.001

Maurage, P., Campanella, S., Philippot, P., Charest, I., Martin, S., and de Timary, P. (2009). Impaired emotional facial expression decoding in alcoholism is also present for emotional prosody and body postures. *Alcohol Alcohol.* 44, 476–485. doi: 10.1093/alcalc/agp037

Maurage, P., Campanella, S., Philippot, P., Pham, T. H., and Joassin, F. (2007). The crossmodal facilitation effect is disrupted in alcoholism: a study with emotional stimuli. *Alcohol Alcohol.* 42, 552–559. doi: 10.1093/alcalc/agm134

Maurage, P., Joassin, F., Pesenti, M., Grandin, C., Heeren, A., Philippot, P., et al. (2013). The neural network sustaining crossmodal integration is impaired in alcohol-dependence: an fMRI study. *Cortex* 49, 1610–1626. doi: 10.1016/j.cortex.2012.04.012

Maurage, P., Philippot, P., Joassin, F., Pauwels, L., Pham, T., Prieto, E. A., et al. (2008). The auditory-visual integration of anger is impaired in alcoholism: an event-related potentials study. *J. Psychiatry Neurosci.* 33, 111–122.

Maurage, P., Rombaux, P., and de Timary, P. (2014). Olfaction in alcohol-dependence: a neglected yet promising research field. *Front. Psychol.* 4:1007. doi: 10.3389/fpsyg.2013.01007

Mogg, K., Philippot, P., and Bradley, B. P. (2004). Selective attention to angry faces in clinical social phobia. *J. Abnorm. Psychol.* 113, 160–165. doi: 10.1037/0021-843x.113.1.160

Mothes-Lasch, M., Mentzel, H. J., Miltner, W. H. R., and Straube, T. (2011). Visual attention modulates brain activation to angry voices. *J. Neurosci.* 31, 9594–9598. doi: 10.1523/JNEUROSCI.6665-10.2011

Naranjo, C., Kornreich, C., Campanella, S., Noël, X., Vandriette, Y., Gillain, B., et al. (2011). Major depression is associated with impaired processing of emotion in music as well as in facial and vocal stimuli. *J. Affect. Disord.* 128, 243–251. doi: 10.1016/j.jad.2010.06.039

Paulmann, S., and Pell, M. D. (2010). Contextual influences of emotional speech prosody on face processing: how much is enough? *Cogn. Affect. Behav. Neurosci.* 10, 230–242. doi: 10.3758/CABN.10.2.230

Paulmann, S., Titone, D., and Pell, M. D. (2012). How emotional prosody guides your way: evidence from eye movements. *Speech Commun.* 54, 92–107. doi: 10.1016/j.specom.2011.07.004

Pell, M. D. (2005a). Nonverbal emotion priming: evidence from the 'facial affect decision task'. *J. Nonverbal. Behav.* 29, 45–73. doi: 10.1007/s10919-004-0889-8

Pell, M. D. (2005b). Prosody-face interactions in emotional processing as revealed by the facial affect decision task. *J. Nonverbal Behav.* 29, 193–215. doi: 10.1007/s10919-005-7720-z

Peschard, V., Philippot, P., Joassin, F., and Rossignol, M. (2013). The impact of the stimulus features and task instructions on facial processing in social anxiety: an ERP investigation. *Biol. Psychol.* 93, 88–96. doi: 10.1016/j.biopsycho.2013.01.009

Philippot, P., and Douilliez, C. (2005). Social phobics do not misinterpret facial expression of emotion. *Behav. Res. Ther.* 43, 639–652. doi: 10.1016/j.brat.2004.05.005

Pishyar, R., Harris, L. M., and Menzies, R. G. (2004). Attentional bias for words and faces in social anxiety. *Anxiety Stress Coping* 17, 23–36. doi: 10.1080/10615800310001601458

Quadflieg, S., Mohr, A., Mentzel, H. J., Miltner, W. H. R., and Straube, T. (2008). Modulation of the neural network involved in the processing of anger prosody: the role of task-relevance and social phobia. *Biol. Psychol.* 78, 129–137. doi: 10.1016/j.biopsycho.2008.01.014

Quadflieg, S., Wendt, B., Mohr, A., Miltner, W. H. R., and Straube, T. (2007). Recognition and evaluation of emotional prosody in individuals with generalized social phobia: a pilot study. *Behav. Res. Ther.* 45, 3096–3103. doi: 10.1016/j.brat.2007.08.003

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/s0005-7967(97)00022-3

Rigoulot, S., and Pell, M. D. (2012). Seeing emotion with your ears: emotional prosody implicitly guides visual attention to faces. *PLoS One* 7:e30740. doi: 10.1371/journal.pone.0030740

Rossignol, M., Philippot, P., Bissot, C., Rigoulot, S., and Campanella, S. (2012). Electrophysiological correlates of enhanced perceptual processes and attentional capture by emotional faces in social anxiety. *Brain Res.* 1460, 50–62. doi: 10.1016/j.brainres.2012.04.034

Sander, D., Grandjean, D., Pourtois, G., Schwartz, S., Seghier, M. L., Scherer, K. R., et al. (2005). Emotion and attention interactions in social cognition: brain regions involved in processing anger prosody. *Neuroimage* 28, 848–858. doi: 10.1016/j.neuroimage.2005.06.023

Schofield, C. A., Coles, M. E., and Gibb, B. E. (2007). Social anxiety and interpretation biases for facial displays of emotion: emotion detection and ratings of social cost. *Behav. Res. Ther.* 45, 2950–2963. doi: 10.1016/j.brat.2007.08.006

Schofield, C. A., Johnson, A. L., Inhoff, A. W., and Coles, M. E. (2012). Social anxiety and difficulty disengaging threat: evidence from eye-tracking. *Cogn. Emot.* 26, 300–311. doi: 10.1080/02699931.2011.602050

Schulz, C., Mothes-Lasch, M., and Straube, T. (2013). Automatic neural processing of disorder-related stimuli in social anxiety disorder: faces and more. *Front. Psychol.* 4:282. doi: 10.3389/fpsyg.2013.00282

Staugaard, S. R. (2010). Threatening faces and social anxiety: a literature review. *Clin. Psychol. Rev.* 30, 669–690. doi: 10.1016/j.cpr.2010.05.001

Van Rheenen, T. E., and Rossell, S. L. (2013). Is the non-verbal behavioural emotion-processing profile of bipolar disorder impaired? A critical review. *Acta Psychiatr. Scand.* 128, 163–178. doi: 10.1111/acps.12125

Vroomen, J., Driver, J., and de Gelder, B. (2001). Is cross-modal integration of emotional expressions independent of attentional resources? *Cogn. Affect. Behav. Neurosci.* 1, 382–387. doi: 10.3758/cabn.1.4.382

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends Cogn. Sci.* 9, 585–594. doi: 10.1016/j.tics.2005.10.011

Vuilleumier, P., Armony, J. L., and Dolan, R. J. (2004). "Reciprocal links between emotion and attention," in *Human Brain Function*, eds R. S. J. Frackowiak, K. J. Friston, C. D. Frith, R. J. Dolan, C. J. Price, S. Zeki, et al. (San Diego: Academic Press), 419–444.

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Fear of negative evaluation modulates electrocortical and behavioral responses when anticipating social evaluative feedback

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Cognitive models posit that the fear of negative evaluation (FNE) is a hallmark feature of social anxiety. As such, individuals with high FNE may show biased information processing when faced with social evaluation. The aim of the current study was to examine the neural underpinnings of anticipating and processing social-evaluative feedback, and its correlates with FNE. We used a social judgment paradigm in which female participants ($N = 31$) were asked to indicate whether they believed to be socially accepted or rejected by their peers. Anticipatory attention was indexed by the stimulus preceding negativity (SPN), while the feedback-related negativity and P3 were used to index the processing of social-evaluative feedback. Results provided evidence of an optimism bias in social peer evaluation, as participants more often predicted to be socially accepted than rejected. Participants with high levels of FNE needed more time to provide their judgments about the social-evaluative outcome. While anticipating social-evaluative feedback, SPN amplitudes were larger for anticipated social acceptance than for social rejection feedback. Interestingly, the SPN during anticipated social acceptance was larger in participants with high levels of FNE. None of the feedback-related brain potentials correlated with the FNE. Together, the results provided evidence of biased information processing in individuals with high levels of FNE when anticipating (rather than processing) social-evaluative feedback. The delayed response times in high FNE individuals were interpreted to reflect augmented vigilance imposed by the upcoming social-evaluative threat. Possibly, the SPN constitutes a neural marker of this vigilance in females with higher FNE levels, particularly when anticipating social acceptance feedback.

Keywords: fear of negative evaluation, social evaluation, feedback anticipation, stimulus preceding negativity, feedback-related negativity, P3, EEG, event-related brain potentials

INTRODUCTION

The fear of negative evaluation (FNE) is considered to be a hallmark of social anxiety. Cognitive theories posit that this fear may result from biased information processing, particularly when anticipating a fearful event (Clark and McManus, 2002). Socially anxious individuals exhibit maladaptive appraisal of social situations, which is characterized by the selective retrieval of negative information about themselves (Rapee and Heimberg, 1997). This biased information is then utilized to make negative self-evaluations (Rapee and Heimberg, 1997; Clark and McManus, 2002). Rapee and Spence (2004) proposed in their influential model that social anxiety can be viewed as lying on a continuum: the lower end of this continuum reflects a total lack of social anxiety, the middle of the continuum marks a strong desire to be positively evaluated, and the highest end of this continuum is marked by an intense fear and avoidance of social situations/interactions. Those individuals who can be placed at the highest end of this continuum meet the criteria of social anxiety disorder or social phobia (Rapee and Spence, 2004; Morrison and Heimberg, 2013). In most cognitive models it is postulated that individuals with social anxiety display a variety of information processing biases (e.g., negative self-referential biases, increased self-focused attention) that generate feelings of anxiety. This anxiety and the negative appraisal of the self contribute to the maintenance of social anxiety by a series of vicious cycles (Clark and McManus, 2002; Morrison and Heimberg, 2013). Neurocognitive theories posit that these information processing biases may be due to aberrant emotion regulation strategies, caused by impaired top-down regulation of negative affect by prefrontal brain structures (Etkin and Wager, 2007; Etkin, 2010; Brühl et al., 2011; Brühl et al., 2013). To date, however, the neural underpinnings of information processing biases related to FNE remain poorly understood. In the current study we focus on the middle end of the social anxiety continuum and will examine the neural underpinnings of social-evaluative feedback anticipation, and the processing thereof. We aim to investigate how individual differences in FNE modulate this neural activity in order to delineate the electrocortical signatures of the information processing biases implicated in social anxiety.

An appealing paradigm to study social evaluation is the social judgment paradigm introduced by Somerville et al. (2006). In this paradigm, participants are shown portrait photographs of unfamiliar peers, and are led to believe that these peers have previously formed impressions about the participant. The participant is asked to judge whether peers either formed positive (i.e., like) or negative (i.e., dislike) impressions. After each judgment, participants are provided with peer feedback that is either congruent or incongruent with their prior expectations. In this study it was shown that valence of the judgment was related to activation of the ventral anterior cingulate cortex (vACC), whereas the dorsolateral anterior cingulate cortex (dACC) was particularly sensitive to violations of participant's expectations. In a follow up study it was demonstrated that the magnitude of the vACC activation to positive social-evaluative feedback was enhanced in individuals with low self-esteem, as compared to individuals with high self-esteem (Somerville et al., 2010). Using the same paradigm, Gunther Moor et al. (2010b) found that the magnitude of this polarization in brain activation followed a linear increase during development. This finding was accompanied by an optimistic self-evaluation bias in 19–25 years old participants. Namely, older participants made significantly more positive social evaluation judgments in comparison to younger participants. This optimistic self-evaluation bias was interpreted in terms of social belongingness theory (Baumeister and Leary, 1995), which states that social acceptance has a high evolutionary value, as it promotes survival and well-being in humans. Accordingly, it has been proposed that social-evaluative threat may serve as a signal that the need for social connection is not being satisfied. In turn, this "need to belong" may augment the desire to form bonds with other people (Maner et al., 2007). Together, the above findings suggest that people have positive expectations about social evaluation by peers, and that this optimism bias is governed by a ventral medial prefrontal neural network, brain regions frequently implicated in self-referential processing and mentalizing (Amodio and Frith, 2006). Interestingly, the magnitude of the polarization in brain activation after receiving positive vs. negative feedback seems subject to individual differences (e.g., levels of self-esteem), suggesting that the social judgment paradigm may be a suitable paradigm to examine biomarkers of social-evaluative fear, a related construct to social anxiety (Watson and Friend, 1969; Rapee and Heimberg, 1997; Weeks et al., 2005; Weeks and Howell, 2012; Levinson et al., 2013).

Due to its fine-grained temporal resolution, investigating event-related brain potentials (ERPs) could add an important dimension to our understanding of individual differences in anticipatory vs. feedback-related processing of social-evaluative information. In a recent study, Van der Veen et al. (2013) investigated feedback ERPs using the social judgment paradigm. Results of this study corroborated the enhanced brain activity after receiving social acceptance feedback. That is, participants displayed a significantly larger P3 component when they were presented with expected social acceptance feedback. However, anticipatory processes were not examined in this study, and the small sample size prohibited the authors from examining individual differences in the processing of social-evaluative feedback.

The purpose of this study was to examine individual differences in neural activity associated with the anticipation of social-evaluative feedback, as well as the processing of this information. We measured FNE in a sample of healthy female adult participants, as it was anticipated that FNE would bias both anticipatory and feedback-related neural activity, as well as behavioral judgments about the social-evaluative outcome. Although FNE only reflects a part of the social anxiety spectrum, namely the interaction anxiety subtype (Mattick and Clarke, 1998), it has been used in a host of studies as an index of non-clinical social anxiety (Wieser et al., 2009; Abraham et al., 2013; Rossignol et al., 2013; Salemink et al., 2013). We measured the stimulus preceding negativity (SPN) as a neural index of anticipatory attention. The SPN is a slow negative potential that progressively increases in amplitude prior to the onset of a feedback stimulus (Böcker and Boxtel, 1997; Brunia et al., 2011). The morphology of the SPN is dependent on the specific task parameters, but SPN amplitudes generally increase for feedback stimuli that convey affective or motivational valence (Böcker et al., 2001). Peak SPN amplitudes display a right lateralized dominance in time-estimation and gambling experiments (Brunia et al., 2011), but the anticipation of appetitive feedback stimuli (e.g., rewarding stimuli) has been associated with left-lateralized dominance of the SPN (Poli et al., 2007). Further, SPN amplitudes seem to be dependent on the level of certainty about the upcoming feedback stimulus, namely, SPN amplitudes have been found to be larger prior to unpredictable – thus uncertain – feedback stimuli (Catena et al., 2012). Since intolerance of uncertainty is posited to be a significant contributor to social-evaluative fears (Whiting et al., 2013), it was anticipated that the SPN would constitute a neural marker of this uncertainty of social evaluation. Moreover, measuring the SPN during the anticipation of both social rejection and acceptance feedback allowed us to examine whether females with high FNE would divert more attention to upcoming rejection or acceptance feedback.

The processing of social-evaluative feedback can be indexed with the feedback-related negativity and P3 components of the feedback-related brain potential. The FRN is a frontocentral negative component peaking approximately 250 ms after feedback onset, whereas the P3 shows peak amplitudes at around 300–600 ms post stimulus. The FRN is typically elicited by feedback stimuli that are incongruent with prior expectations, and is frequently interpreted to reflect performance monitoring (Van Noordt and Segalowitz, 2012). In contrast, the P3 is considered to be a more cognitive component, governed by top-down attentional control mechanisms (Polich, 2007). A recent study revealed that P3 amplitudes in the social judgment paradigm were larger for positive than for negative feedback (Van der Veen et al., 2013), a finding that was interpreted to reflect a confirmation of social acceptance and its inherent feeling of reward.

In the current study we examined the following hypotheses: (1) conform findings of Gunther Moor et al. (2010b) and in line with Social Belongingness Theory (Baumeister and Leary, 1995), we hypothesized an optimism bias in our participant sample – such that participants would anticipate social acceptance more often than social rejection; (2) Based on the notion that socially anxious individuals anticipate social rejection more often (Clark and McManus, 2002), it was anticipated that this optimistic self-evaluation bias would only be present in females with low FNE levels; (3) In line with the notion of the uncertainty hypothesis of the SPN (Catena et al., 2012), we expected that SPN amplitudes would be larger for social acceptance than for rejection judgments in females with higher FNE levels, since females high in FNE may expect rejection more often, rendering social acceptance more unlikely; (4) Based on fMRI results showing increased brain activation after receiving positive-evaluative feedback (Somerville et al., 2006; Gunther Moor et al., 2010b; Somerville et al., 2010), we anticipated larger P3 amplitudes when feedback communicated social acceptance. It was hypothesized that this effect would be more pronounced in females with higher FNE levels, since P3 amplitude is modulated both by valence and expectancy (Ferdinand et al., 2012). As we anticipated that females high in FNE would predict social acceptance less often, feedback signaling acceptance would be more surprising and thus render larger P3 amplitudes.

MATERIALS AND METHODS

PARTICIPANTS

Thirty-one female participants aged between 18 and 24 years (mean age = 19.78; SD = 1.45) participated in this study. All participants were right handed as verified with the Edinburgh Handedness Inventory (Oldfield, 1971) and had no history of neurological or psychiatric disorders. Participants had normal or corrected-to-normal vision, and were free from psychoactive medication. Participants were recruited from or within the proximity of the university, provided signed informed consent, and were awarded course credit or fixed payment for their participation. None of the participants had any doubts about the cover story (see Experimental design and procedure). The protocol for this study was reviewed and approved by the medical ethical review committee of the Leiden University Medical Center.

FEAR OF NEGATIVE EVALUATION

Fear of negative evaluation was assessed with the Dutch translated brief version of the *Fear of Negative Evaluation Scale, revised* (BFNE-R; Bögels and Reith, 1999; Carleton et al., 2006). The BFNE-R has demonstrated excellent levels of internal consistency and test–retest reliability, correlates highly with the full scale FNE, and is a commonly used measure of social anxiety (Collins et al., 2005; Carleton et al., 2011). The BFNE-R consists of 12 statements about social-evaluative situations. Participants have to indicate on a 5-point Likert scale the degree to which each statement applies to them (0 = not at all characteristic of me; 4 = extremely characteristic of me). Carleton et al. (2011) showed that a cut-off score of 38 can be employed to specify individuals showing clinical signs of social anxiety disorder. An excellent internal consistency was obtained for the items within the current sample (α = 0.95). To test the validity of the FNE scores, we measured levels of social anxiety, self-esteem, behavioral inhibition, and rejection sensitivity, with the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987), the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1965), Behavioral Inhibition Scale (BIS; Carver and White, 1994), and Rejection Sensitivity Questionnaire (RSQ; Downey and Feldman, 1996), respectively. Mean scores on the self-report measures are presented in **Table 1**. The FNE correlated significantly with all measures and yielded good-to-excellent internal consistencies (see **Table 2**).

EXPERIMENTAL DESIGN AND PROCEDURE

A modified version of the social judgment paradigm was used (Somerville et al., 2006; Gunther Moor et al., 2010b). With a cover story, participants were led to believe that they would participate in a study on first impressions. Approximately 2 weeks prior to the experimental session, participants were asked to send a personal portrait photograph to the investigators. A panel of peer undergraduate students from other universities would evaluate this photograph, and provide a judgment based on their first impressions (i.e., like or dislike the person on the photograph). At the day of the experiment, participants completed the social judgment paradigm together with another cognitive task (order of presentation was counterbalanced between participants) of which the data will not be presented in this study. Prior to the social judgment experiment, participants were told that they would see portrait photographs of each member of this panel of peers. Their task was to judge whether this peer member liked or disliked the participant. A total of 160 photographs of peers were used (50% male), derived from taking photographs of undergraduates from different universities. Photos of the peers were presented at a 17-inch monitor [60 Hz refresh rate; visual angle (width/height) = (4.66° × 6.05°)] using

Table 1 | Means, standard deviations (SD) and range (minimum–maximum) of the scores on the self-reported questionnaires.

Questionnaire	Mean (SD)	Range (min.–max.)
Fear of Negative Evaluation (FNE)	23.00 (11.35)	4–47
Social Anxiety (LSAS)	35.48 (15.33)	12–87
Self-Esteem (RSES)	9.77 (4.91)	1–18
Rejection Sensitivity (RSS)	7.82 (3.81)	2.78–14.61
Behavioral Inhibition (BIS)	22.26 (3.45)	16–27

Table 2 | Internal consistencies of the questionnaires used to index social anxiety, self-esteem, rejection sensitivity, and behavioral inhibition.

Questionnaire	Cronbach's alpha	Correlation with FNE
Social Anxiety (LSAS)	0.91	$r(31) = 0.36$, $p = 0.045$
Self-Esteem (RSES)	0.87	$r(31) = 0.63$, $p < 0.0001$
Rejection Sensitivity (RSS)	0.88	$r(31) = 0.59$, $p = 0.001$
Behavioral inhibition (BIS)	0.86	$r(31) = 0.56$, $p = 0.001$

Scores on these measures correlated positively with scores on the fear of negative evaluation (FNE) questionnaire.

E-prime 2.0 stimulus presentation software (Psychology Software Tools, Pittsburgh, PA, USA). All peer photographs had a neutral facial expression, as ascertained with the Self-Assessment Manikin (SAM) on a 9-point scale (Bradley and Lang, 1994). These SAM-ratings of arousal and valence were obtained from an independent sample of volunteers ($N = 21$), gender and age-matched to the participants.

An illustration of a single trial is shown in **Figure 1**. Each trial commenced with the depiction of the cue for 3000 ms displaying the neutral face of the peer. The cue remained on the screen until the end of the trial. During this 3000 ms interval, participants were required to provide their positive (i.e., "acceptance") or negative (i.e., "rejection") judgments by pressing one of two buttons on an armrest. The order of which button (left or right) corresponded with acceptance ("YES") or rejection ("NO") anticipations was counterbalanced between participants. If participants did not respond within 3000 ms after onset of the cue, the message "too slow" appeared on the screen signaling the end of the trial. Participants were instructed that they had about 3000 ms to provide their judgment. Participants were told that they did not have to respond as fast as possible, but rather they had to seriously evaluate whether the person on the photograph liked or disliked the participant. Trials on which participants responded too slow (i.e., after 3000 ms from cue onset) were excluded from the analysis. When participants provided their judgment, a visualization of their response ("YES" or "NO") was immediately displayed to the left of the peer's face. After a fixed delay of 3000 ms (i.e., the anticipation period), feedback appeared to the right of the peer's face for 2000 ms, communicating either social acceptance ("YES") or rejection ("NO"). Social rejection feedback ("NO") was presented on 50% of the trials[1]. Feedback in this paradigm was not actual peer-feedback, but fictitious feedback that was pseudo-randomly generated by the computer, such that at least on 50% of the trials participants received acceptance feedback. Between trials, a fixation cross was presented in the center of the screen with a jittered duration between 500 and 1500 ms. Participants started with 10 practice trials, and then completed three experimental blocks comprising 50 trials each. At the end of the experiment, electroencephalography (EEG) equipment was detached and participants were asked to write down their experiences and thoughts about the experiment. Subsequently, participants filled out the abovementioned questionnaires. None of the participants had doubts about the cover story. Participants were debriefed about the true purpose of this study by letter after the last participant was examined.

BEHAVIORAL ANALYSIS

The following behavioral data was used for analysis: the number of acceptance and rejection judgments, as well as the reaction time (RT) that was needed to provide these judgments. A bias score was calculated to examine whether participants anticipated significantly more acceptance than rejection feedback (Van der Veen et al., 2013). This bias score was derived from

[1]The presentation of the participants' judgments (i.e., to the left of the face) and the feedback (i.e., to the right of the face) may result in contralateral event-related brain activity. As we were only interested in the events prior to (SPN) and during feedback-processing (FRN/P3), participant's attention to the right visual field may be associated with ERP maxima over the left hemisphere. However, this potential lateralization confound would not affect the hypothesized amplitude differences in the SPN and feedback-related conditions, as lateralization of stimuli did not vary by condition.

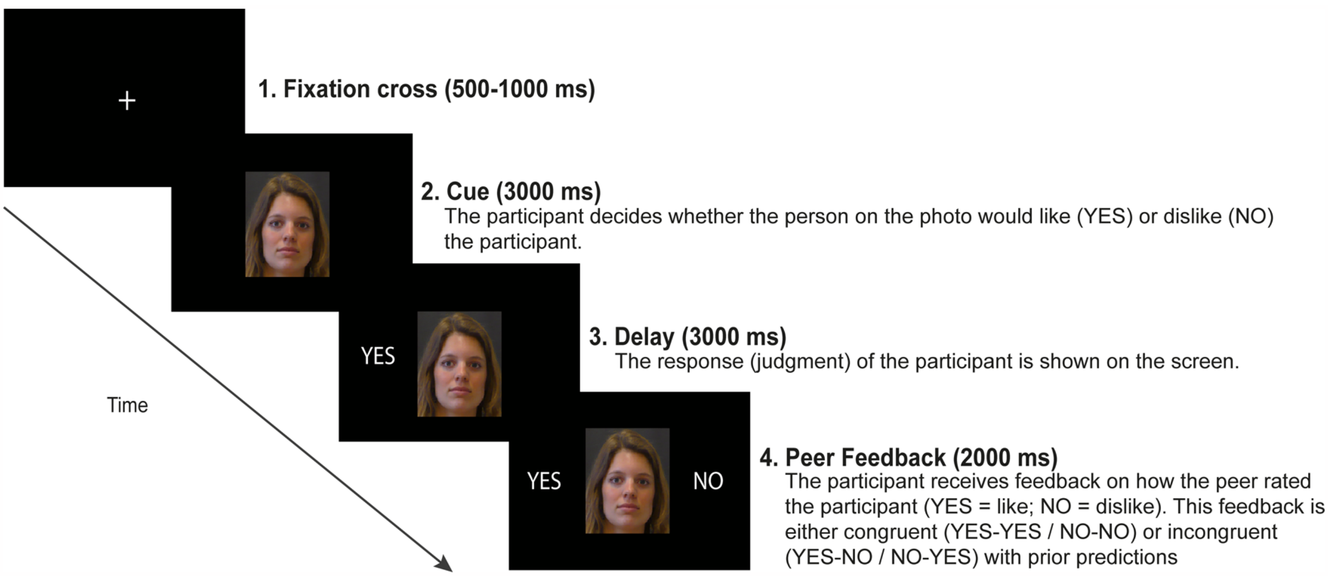

FIGURE 1 | An illustration of a single trial in the social evaluation paradigm. On each trial, participants are presented with a photograph of a peer. The participant is asked to judge whether the peer would either like (accept) or dislike (reject) the participant. Based on judgment type ("YES" or "NO") and feedback type ("YES" or "NO"), four possible feedback conditions were included: expected social acceptance ("YES–YES"), expected social rejection ("NO–NO"), unexpected social acceptance ("NO–YES"), or unexpected social rejection ("YES–NO"). This particular trial shows an example of unexpected social rejection.

dividing the number of acceptance judgments by the number of total judgments. This bias score either reflects an optimism bias (>50%) or a pessimism bias (<50%).

EEG RECORDING AND SIGNAL PROCESSING

Electroencephalography time series were recorded at a 1024 Hz sampling rate from 64 Ag–AgCl electrodes mounted in an elastic electrode cap (10/20 placement) using a BioSemi Active Two system (Biosemi, Amsterdam, The Netherlands). The BioSemi system replaces the ground electrode by a feedback loop consisting of the common mode sense (CMS) electrode and Driven right leg (DRL) electrode; CMS was used as the online reference. Horizontal electrooculography (HEOG) was measured from two electrodes placed at the left and right canthus; vertical EOG (VEOG) was measured from two electrodes placed above and below the left eye. Two electrodes were placed at the mastoids. Offline processing of the EEG was performed with Brain Vision Analyzer 2 (Brain Products GmbH). The EEG signal was down-sampled to 512 Hz, re-referenced to the average of the left and right mastoids and offline band-pass filtered between 0.1 and 40 Hz (24 dB/oct), with a 50 Hz notch filter. Ocular artifacts were removed automatically using the Infomax Ocular ICA method as implemented in Brain Vision Analyzer. Subsequently, segments were created to isolate the SPN and feedback-related brain potentials (FRN and P3). All segments were visually inspected for remaining artifacts. The average number of segments used for analyses of the SPN and feedback-related components is presented in **Table 3**.

To isolate the SPN, 3500 ms segments were created including a 200 ms post feedback-stimulus interval. These segments included the participants' judgments (responses) occurring at 3000 ms prior to the onset of the feedback stimulus. The 2400–2000 ms interval was used for baseline correction, as this time period most likely is the start of the anticipation period and visual inspection verified the absence of any residual motor activity. Previous studies have shown that setting baseline corrections prior to motor responses may confound the SPN by including anticipatory activity associated with the response preparation (Brunia et al., 2011). In line with prior studies, the SPN was calculated using a mean amplitude measurement within the 200 ms interval prior to the onset of the feedback stimulus at the Fz electrode (Kotani and Aihara, 1999; Ohgami et al., 2006; Stavropoulos and Carver, 2013). Although the SPN usually reaches peak amplitude at frontal electrode sites (Böcker et al., 2001; Brunia et al., 2011) data from the parietal–occipital electrodes PO7 and PO8 were analyzed also, as visual inspection of the data revealed that the SPN reached largest amplitudes over these leads in both anticipation conditions[2].

To isolate the feedback-related ERPs, 1200 ms epochs were created including a 200 ms pre-stimulus interval, which was used for baseline correction. FRN amplitude was measured using the peak-to-peak method described by Holroyd et al. (2003), since a single peak measurement often confounds FRN amplitude due to overlap with the earlier P2 component (Luck, 2005). In line with Holroyd et al. (2003), the onset of the FRN was determined by finding the most positive peak within a 200–300 ms time window (i.e., the P2 component). From the onset of the negativity, the most negative peak was determined within the 250–350 ms time window. FRN amplitudes were obtained by subtracting the P2 peak from this most negative value. Finally, the feedback-related P3 component was examined by calculating the mean amplitude in a time window between 360 and 440 ms, as recommended by Luck (2005).

Table 3 | Means, standard deviations (SD), and range (minimum–maximum) of the number of trials that were used to calculate the SPN and the feedback-related brain potentials.

Component (condition)	Mean (SD)	Range (min.–max.)
SPN (predicted acceptance)	74.42 (13.32)	44–104
SPN (predicted rejection)	59.98 (12.63)	29–90
Feedback (expected acceptance)	36.98 (7.09)	20–55
Feedback (unexpected rejection)	37.22 (8.75)	19–57
Feedback (expected rejection)	29.98 (8.22)	13–49
Feedback (unexpected acceptance)	30.02 (6.64)	14–46

STATISTICAL ANALYSES

Statistical Analyses were performed in three successive steps: (1) Task performance was analyzed using a one-sample *t*-test to verify a significant difference in judgment type. Pearson product-moment correlation was performed to examine the correlation between judgment type and level of FNE; (2) Anticipatory brain activity (SPN) was assessed using a repeated measures ANOVA with Site (three levels: Fz, PO7, PO8) and Judgment (two levels: acceptance, rejection) as within-subject factors to test where the SPN reached peak amplitude, and whether this differed between Judgment types. *Post hoc* analyses were performed to explore significant main or interaction effects; (3) For the feedback-related ERPs, a repeated measures analysis was performed, separately for the FRN and P3, with the within-subject factors Congruency (two levels: congruent, incongruent) and Valence (two levels: positive, negative). *Post hoc* analyses were performed to explore significant main or interaction effects. Pearson product-moment correlation analyses were performed to test our behavioral and ERP hypotheses. Bonferroni corrections for multiple comparisons were applied. Statistical analyses were performed using IBM SPSS Statistics 19 (IBM Corporation, 2010). The behavioral and EEG data were inspected for outliers (i.e., data points above or below two standard deviations of the sample's mean). No outliers were detected. Alpha was set at 0.05 and additional *post hoc* significance testing was performed using Bonferroni correction for multiple comparisons. Greenhouse–Geisser correction was applied when necessary, and non-adjusted degrees of freedom were reported for transparency[3].

[2]We also analyzed the SPN in an 800 ms time-window before the onset of the feedback using a mean amplitude calculation. This analysis did not yield significant differences from the 200 ms time-window analysis. As can be seen in **Figure 2**, the difference in SPN amplitude are most pronounced during the last 200 ms, indicating that the 200 ms time-window best reflects the anticipatory process (Poli et al., 2007).

[3]A *post hoc* power analysis was run to determine whether our participant sample was large enough to obtain appropriate statistical power. Results of this analysis revealed that a sample of $N = 37$ is required to obtain an appropriate level of statistical power at 0.80. Therefore any conclusions about the significance of the results presented below were made with a certain level of caution.

RESULTS

TASK PERFORMANCE

An average response bias score of 56% (SD = 0.09) was observed indicating that participants displayed an optimism bias in anticipating more social acceptance feedback. A one-sample *t*-test verified that this bias score differed significantly from the baseline (i.e., 50%), as participants anticipated acceptance feedback (Mean number of trials = 82.42, SD = 13.76) more often than rejection feedback (Mean number of trials = 65.68, SD = 14.17), $t(30) = 3.36$, $p = 0.002$. Next, we tested the hypothesis that females with higher levels of FNE would anticipate rejection feedback more often, however, no significant positive correlation yielded between FNE scores and the percentage of negative judgments, $r(31) = 0.30$, $p = 0.106$.

Subsequently, we analyzed the RT data of the anticipated acceptance and rejection judgments using a one-sample *t*-test. No significant differences were observed in the RT of acceptance (Mean RT = 1366.91, SD = 274.85) and rejection judgments (Mean RT = 1391.34, SD = 266.66). However, as shown in **Figure 2**, a Pearson product-moment correlation analysis revealed that females with higher FNE-S scores displayed longer RTs for predicting acceptance, $r(31) = 0.44$, $p = 0.014$, and rejection feedback, $r(31) = 0.41$, $p = 0.021$. This response time effect remained significant after controlling for the effect of behavioral inhibition for predicting acceptance ($p = 0.013$) and rejection feedback ($p = 0.022$), respectively.

ANTICIPATORY BRAIN ACTIVITY: STIMULUS PRECEDING NEGATIVITY

Results of average SPN amplitudes per judgment type are depicted in **Figure 3** for the Fz, PO7, and PO8 electrodes. Peak SPN amplitudes within the 200 ms time-window before the onset of the feedback stimulus were extracted from the Fz, PO7, and PO8 electrodes (see **Figure 3**). As revealed by a main effect of Site, SPN peak amplitude was larger at PO7 than at Fz and PO8, $F(1,30) = 9.16$, $p = 0.005$, $\eta^2_p = 0.23$. The main effect of Judgment revealed that the SPN was more negative for acceptance than for rejection judgments, $F(1,30) = 6.21$, $p = 0.018$, $\eta^2_p = 0.23$. No significant interaction between site and judgment was observed, $F(2,60) = 0.05$, $p = 0.950$, $\eta^2_p = 0.00$. Pearson product-moment correlation analyses revealed a significant correlation between the RT for anticipated social rejection judgments and the corresponding SPN, $r(31) = -0.48$, $p = 0.001$ (see **Figure 3**).

CORRELATIONS BETWEEN THE SPN AND FNE

A subsequent step was to examine whether SPN amplitudes during anticipated social acceptance or rejection could predict the level of FNE, as indexed with the FNE. Pearson correlations were run between the SPN amplitudes during positive and negative feedback anticipation, respectively, with the FNE scores. SPN amplitudes at the PO7 were used, since SPN amplitudes were largest at this lead. As shown in **Figure 4**, SPN amplitudes associated with acceptance judgments correlated significantly with FNE-S scores, $r(31) = -0.37$, $p = 0.021$. No significant correlation was found between the SPN associated with anticipated social rejection and FNE-S scores.

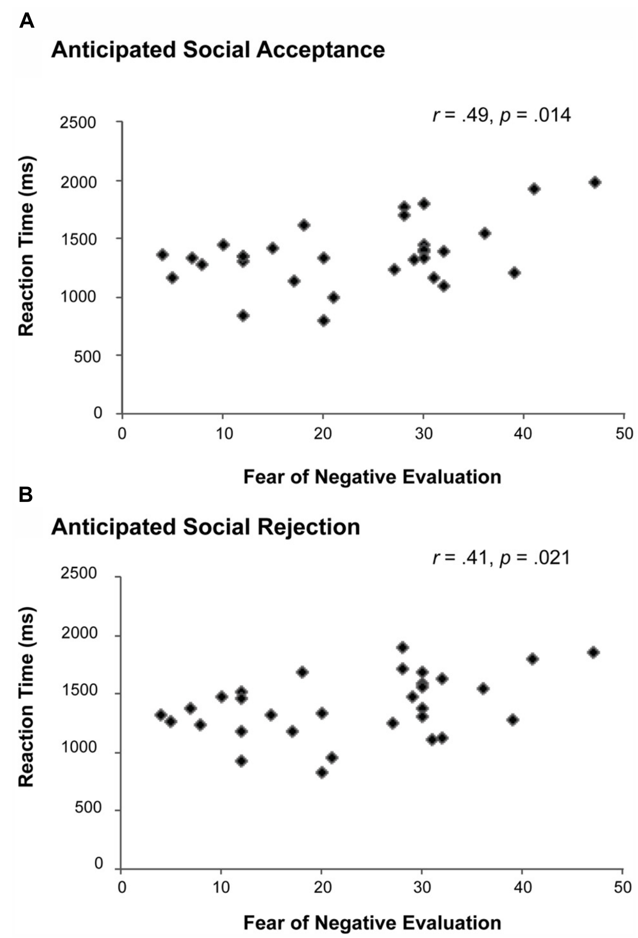

FIGURE 2 | Correlations between the Fear of Negative Evaluation (FNE) and the RT of social acceptance (A) and social rejection (B) judgments. Individuals with higher levels of FNE needed significantly more time to provide both social acceptance ("YES") and social rejection ("NO") judgments.

FEEDBACK RELATED BRAIN ACTIVITY: FRN AND P3

Brain potentials elicited by the feedback stimuli are depicted in **Figure 5**. Peak FRN amplitudes at electrode FCz were submitted to a repeated measures analysis with Congruency (two levels: congruent, incongruent) and Valence (two levels: positive, negative) as within-subject factors. The main effect of congruency revealed that FRN amplitudes for incongruent feedback were larger than for congruent feedback, however, this difference just failed to reach levels of significance, $F(1,30) = 3.84$, $p = 0.059$, $\eta^2_p = 0.11$. The main effect of valence was also not significant, $F(1,30) = 1.04$, $p = 0.317$, $\eta^2_p = 0.03$, suggesting that FRN amplitude did not differ between positive and negative feedback. No significant interaction between Congruency and Valence was observed, $F(2,60) = 0.00$, $p = 0.953$, $\eta^2_p = 0.00$.

Peak P3 amplitudes at Pz were submitted to a repeated measures analysis with Congruency (two levels: congruent, incongruent) and Valence (two levels: positive, negative) as within-subject factors. As expected, P3 amplitudes for unexpected feedback did not differ from expected feedback, $F(1,30) = 0.08$, $p = 0.783$,

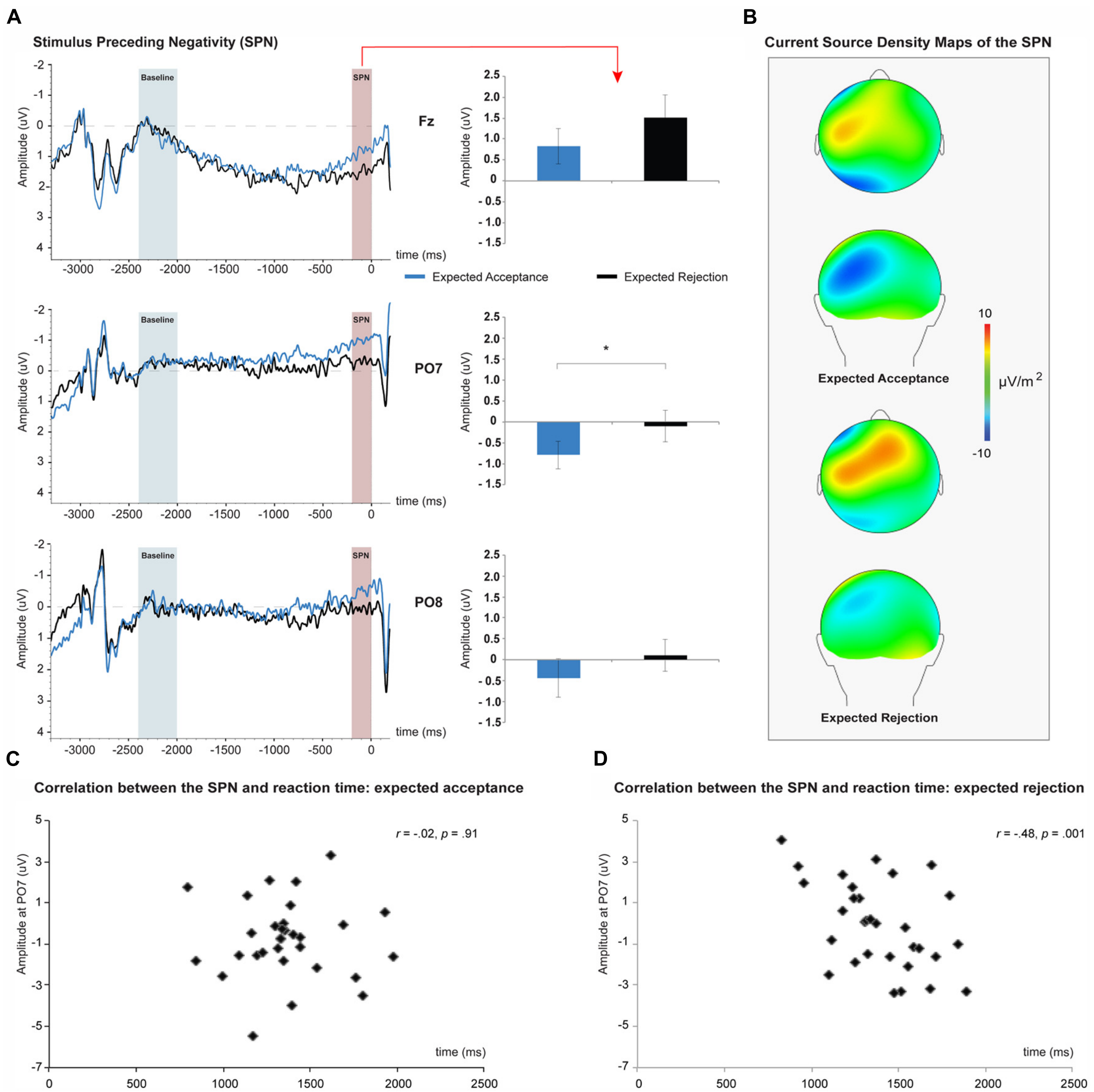

FIGURE 3 | The stimulus preceding negativity (SPN) associated with social-evaluative feedback anticipation. SPN amplitudes were larger for expected social acceptance than for social rejection, and reached peak amplitudes at PO7 **(A)**. Current source density maps show the left posterior dominance of the SPN **(B)**. Correlations between SPN amplitude and reaction time (RT) of the judgments for expected social acceptance **(C)** and social rejection **(D)** feedback. An increase in SPN amplitude during expected social rejection was associated with a significant increase in RT of the corresponding judgment. $*p < 0.05$.

$\eta_p^2 = 0.00$. In contrast with our expectations, the main effect of Valence was also not significant, $F(1,30) = 1.50$, $p = 0.230$, $\eta_p^2 = 0.05$, suggesting that P3 amplitude was not significantly larger for positive than for negative social-evaluative feedback. No significant interaction between Congruency and Valence was observed for the P3, $F(2,60) = 0.04$, $p = 0.849$, $\eta_p^2 = 0.03$.

CORRELATIONS BETWEEN THE SPN AND FEEDBACK-RELATED BRAIN POTENTIALS

Next, Pearson product-moment correlations were run between the SPN and feedback-related brain potentials. We examined these correlations between SPN and the feedback components separately for anticipated acceptance and anticipated rejection. This resulted in two sets of eight correlations for (1) the SPN during anticipated acceptance versus the FRN and P3 in the four conditions (i.e., expected acceptance/rejection, unexpected acceptance/rejection), and (2) the SPN during anticipated rejection versus the FRN and P3 in the four conditions (i.e., expected acceptance/rejection, unexpected acceptance/rejection). Bonferroni correction for multiple comparisons was used (i.e., $p < 0.006$). Results revealed that an increase in SPN amplitude in the anticipated acceptance condition ("Yes" anticipations) was associated with a significant increase in P3 amplitude after anticipated

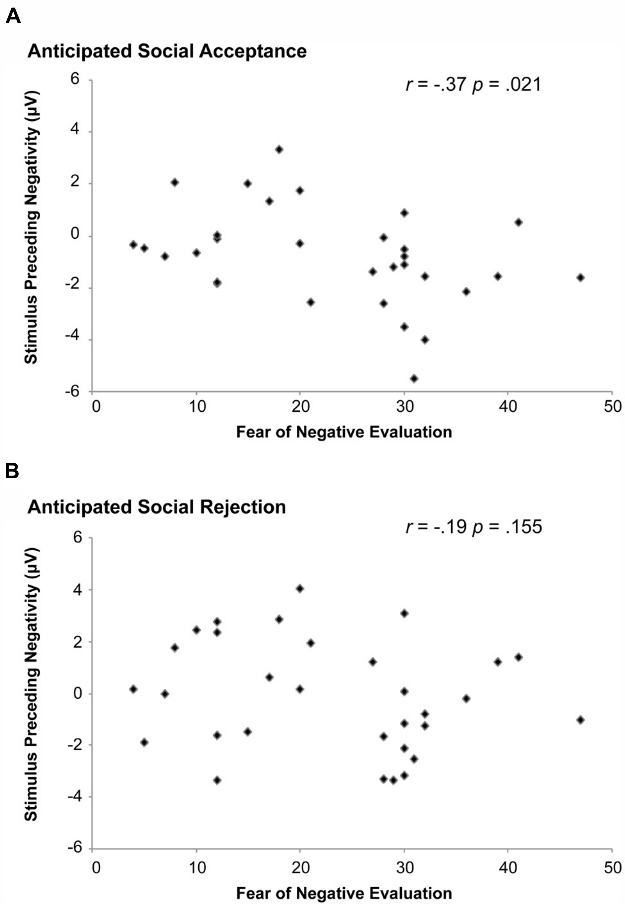

FIGURE 4 | Correlation between SPN amplitude and the fear of negative evaluation (FNE). A significant correlation was observed between the SPN and FNE when participants were anticipating social acceptance **(A)**. This effect was not observed when participants were anticipating social rejection **(B)**.

acceptance ("Yes" feedback), $r(31) = -0.47$, $p = 0.004$. Partial correlation analysis revealed that this effect did not remain significant after controlling for levels of FNE, $r(31) = 0.42$, $p = 0.021$.

CORRELATIONS BETWEEN FEEDBACK-RELATED BRAIN ACTIVITY AND FNE

Lastly, we examined whether feedback-related brain activity correlated with FNE. However, no significant results were observed (all p's > 0.006).

DISCUSSION

The impetus of this study was to investigate precursors of fear of social evaluation by examining behavioral and electrophysiological correlates of social-evaluative feedback anticipation and processing. We used a social-judgment paradigm in which participants were asked to indicate whether they believed to be accepted or rejected by their peers. In line with our hypothesis, results provided evidence of an optimism bias in social peer evaluation; namely, participants more often predicted to be socially accepted than rejected by peers. We did not find evidence for our hypothesis that the number of social rejection judgments correlated positively with the level of FNE in female participants. Interestingly, however, the current study shows that an increase in FNE levels corresponded with a significant increase in the response time of the participants to provide their judgments about upcoming social evaluation. The SPN – a brain potential associated with feedback anticipation – was larger during anticipated acceptance than rejection feedback. Furthermore, SPN amplitudes correlated positively with the level of FNE when participants were anticipating social acceptance feedback. Together, the current study provides evidence of information processing biases during social-evaluative feedback anticipation in adult females, which are modulated by the level of FNE.

In line with our hypothesis, we observed a significantly larger proportion of acceptance judgments compared to rejection judgments. This corroborates previous findings of two studies by Gunther Moor et al. (2010a,b), and may be indicative of an optimistic self-evaluation bias. Hepper et al. (2011) recently demonstrated that expectations about social-evaluative feedback are generally positive, a finding that was interpreted to reflect the situational motivation to self-enhance. According to self-enhancement theory, people have the tendency to see themselves better than they actually are (Taylor and Brown, 1988). Thus, people may anticipate more positive than negative self-evaluations. This optimistic self-evaluation bias is also in accordance with social belongingness theory (Baumeister and Leary, 1995), which states that people have a fundamental need for positive social relationships. This desire of social belongingness is an evolutionary-rooted human motivation to form and maintain social bonds, since these social bonds increase the chances for socio-emotional and physical well-being (Macdonald and Leary, 2005). The strength of this "need to belong" has furthermore been demonstrated by Maner et al. (2007), who observed that even the experience of social exclusion elicited the desire to form social bonds with other people and allocate positive evaluations to others, in the hope to establish renewed social connections.

In the current study, we examined whether this optimistic self-evaluation bias was related to levels of FNE as well as levels of generalized social anxiety (LSAS), but we found no evidence for such a correlation. We did find that participants with higher levels in FNE were significantly slower in judging whether social-evaluative feedback was positive or negative. This increment in response time in those females higher in FNE may be due to increased self-focused attention and vigilance imposed by the task demands, which could subsequently compromise information processing efficiency. In the current study, the social-evaluative threat may have prompted an increase in self-focused attention – a stimulus-driven process that is posited to interfere with disengaging attention from socially threatening stimuli – fueling maladaptive cognitions, and resulting in a greater effort in preparing responses (Judah et al., 2013). Although speculative, mainly due to the absence of an objective measure of self-focused attention in the current study, this notion is in line with the attentional control theory (ACT), which states that anxiety impairs processing efficiency in conditions

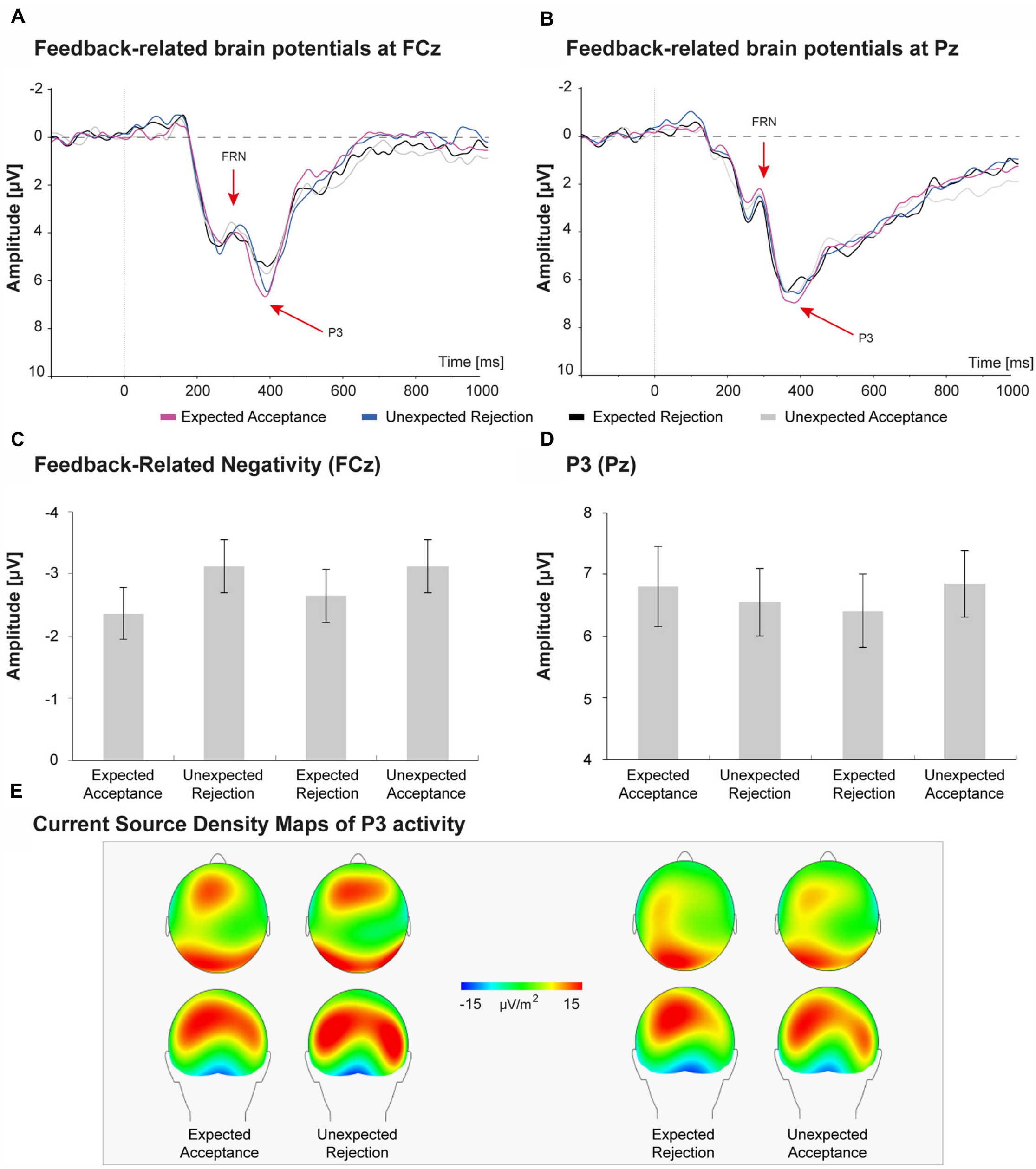

FIGURE 5 | Feedback-related brain potentials elicited by social acceptance and rejection feedback (A,B). FRN amplitudes were largest at FCz **(A)**, whereas the P3 reached peak amplitudes at Pz **(B)**. **C,D** shows peak amplitudes of the FRN and P3 for the four social-evaluative feedback conditions. The FRN seems sensitive to congruency of feedback; however, this effect was not significant. The P3 seems larger for social acceptance feedback than for social rejection feedback, but also these differences were not significant. **E** displays the current sources density maps of P3 activity.

that place a high demand on cognitive resources (Eysenck et al., 2007).

At the electrocortical level, we observed that SPN amplitudes were significantly larger when participants were anticipating social acceptance compared to social rejection feedback. The left parietal–occipital predominance of the SPN was most likely due to the switch of attention to the contralateral visual field, since feedback stimuli were presented right from the photographs of peers. The functional significance of the SPN is often debated, but there is accumulating evidence suggesting that the SPN reflects affective motivational anticipatory processes (Poli et al., 2007; Brunia et al., 2011). A host of electrophysiological studies revealed that SPN amplitudes tend to be larger for stimuli that are rewarding (Ohgami et al., 2004; Mattox et al., 2006; Ohgami et al., 2006; Stavropoulos and Carver, 2013). In the current study, receiving social acceptance feedback would be more rewarding than rejection feedback, which could be related to the enhanced SPN amplitudes when participants were anticipating social acceptance.

This interpretation meshes with the aforementioned social belongingness theory, namely that participants were anticipating social acceptance more often than rejection, as social acceptance facilitates the formation of new social bonds and general wellbeing of the individual.

An alternative account on the functionality of the SPN is the "uncertainty hypothesis", which posits that the SPN would be larger when predictions are made for highly unpredictable or uncertain outcomes (Catena et al., 2012). In the current study we observed that SPN amplitudes were larger in participants who were slower in providing their judgment about upcoming social rejection feedback. This slowing in response time for predicting social rejection feedback may be indicative of uncertainty about social rejection, as the optimistic self-evaluation bias revealed that participants more often predicted to be socially accepted. However, this interpretation is in stark contrast to the observation that SPN amplitudes were larger when participants anticipated to be socially accepted. Moreover, results showed that SPN amplitudes correlated positively with the levels of FNE when participants anticipated social acceptance. Based on the uncertainty hypothesis it was a priori expected that females with higher levels of FNE would anticipate social rejection more often, thereby rendering social acceptance as less likely and therefore uncertain. Due to the absence of a pessimistic self-evaluation bias in females with higher levels of FNE, it seems unlikely that the augmented SPN in high FNE females can be explained by uncertainty about the social-evaluative outcome. The larger SPN amplitudes when anticipating social acceptance feedback may be reflective of the intrinsic motivation to be socially accepted, which dovetails with the aforementioned social belongingness theory (Baumeister and Leary, 1995). Also, the distribution of FNE scores in the current sample indicated that only a few participants ($N = 3$) met the criteria for higher levels of social anxiety (Carleton et al., 2011), whereas the majority of the participants could be placed on the middle range of the social anxiety continuum (Rapee and Spence, 2004). According to Rapee and Spence (2004), these individuals can often be characterized by having a strong desire to be positively evaluated. Future studies should examine whether the behavioral and electrocortical findings will be exaggerated in participants with clinical levels of social anxiety, or whether these participants will (1) anticipate rejection feedback more often, and (2) will display a differential pattern of brain activation during social-evaluative feedback anticipation.

The processing of social-evaluative feedback was indexed by the FRN and P3. Results revealed that feedback that violated prior anticipations (e.g., unexpected acceptance and unexpected rejection) was associated with larger FRN amplitudes, relative to feedback that was congruent with prior anticipations; however, this incongruency effect just failed to reach levels of significance. The FRN is typically seen after incongruent feedback communicating unexpected feedback or poor performance (Van Noordt and Segalowitz, 2012). Although social-evaluative feedback in the current study could be incongruent with prior expectations, the absence of a significant incongruency effect may be explained by the fact that incongruent feedback did not communicate task performance. That is, FRN amplitudes may be larger for incongruent feedback that can be used to optimize future task performance. Based on prior neuroimaging findings of Somerville et al. (2006), we anticipated a pronounced FRN in this study, since a candidate source of the FRN (i.e., the ACC) seems differentially activated by social-evaluative feedback and expectancy violations. These authors found that the dorsal ACC was particularly activated by incongruent feedback, whereas the vACC was activated by acceptance feedback. The surface EEG potentials in the current study evidently lacked the fine-grained spatial resolution to pick up these differences.

Based on recent findings of Van der Veen et al. (2013) we anticipated finding a larger P3 component when social-evaluative feedback communicated acceptance. Indeed, anticipated social acceptance feedback elicited largest P3 amplitudes, and an overall trend was observed in the current study suggesting that the P3 was larger for acceptance than rejection feedback. However, these differences were not significant. This could be due to differences in sample size between our study ($N = 31$) and the Van der Veen et al. (2013) study ($N = 17$), and/or differences in the number of experimental trials. The current study does add an important dimension to the interpretation of the enhanced P3 after anticipated social acceptance feedback reported by Van der Veen et al. (2013). Namely, we found that an increase in SPN amplitude during anticipated social acceptance correlated significantly with P3 amplitudes in this condition. This finding is in accord with neuroimaging results reported by Gunther Moor et al. (2010b), showing enhanced vACC activity to social acceptance feedback in those individuals who also expected to be liked. These authors postulated that social acceptance is more salient when individuals also anticipate to be accepted. The current correlation between the SPN (anticipation) and P3 (feedback processing) may provide further support for this notion.

There are a few limitations to the current study. First, the limited sample size ($N = 31$) and the use of an undergraduate sample of female participants (instead of using a group comparison between healthy controls and a clinical sample) impede the generalization of the current findings to patients with social anxiety disorder. Second, no causal interferences can be made from the correlational analyses with respect to FNE or social anxiety. Moreover, given the absence of a correlation between self-reported social anxiety (LSAS) with the behavioral and electrocortical data, the current findings may only be related to a certain aspect of the social anxiety spectrum, namely social-evaluative threat. Therefore our findings are preliminary and in future studies it will be important to examine whether this pattern of findings exists in a group of clinically diagnosed socially anxious patients. A third limitation of the current experimental design is that the psychological experience of predicting to be liked or disliked perfectly covaries with the physical attributes of the feedback stimulus (i.e., the word "yes" or "no"). Since no counterbalancing was possible using these feedback stimuli, differences in SPN amplitude between conditions may partly be due to the imagination of these feedback stimuli while anticipating this type of feedback. We argue that this effect would be negligible; however, futures studies may consider using different feedback stimuli (e.g., symbols) that are presented in a counterbalanced fashion. Fourth, our participants were not asked about their subjective estimates of the relative proportion of receiving positive or negative feedback, before and after the study. This information could yield individual differences in subjective estimation of the proportion of acceptance or rejection feedback that participants received. For example, participants higher in FNE may overestimate the proportion of social rejection feedback. Although we did not find such differences based on the actual judgments during the task, Somerville et al. (2010) demonstrated that participants with high self-esteem overestimated the proportion of social acceptance feedback. Future studies should ask this information from participants in exit interviews, as this may shed light on perceptual biases in interpreting social-evaluative outcomes.

In conclusion, by investigating both behavioral and electrocortical correlates of social-evaluative processes, the current study demonstrates that individuals high in FNE display information processing biases during the anticipatory stages of social evaluation. In contrast to the prevailing notion that socially anxious individuals anticipate to be socially rejected, we did not find evidence that confirmed this bias in females with higher FNE levels. Results did show, however, that females higher in FNE needed more time to make their judgments about an upcoming social-evaluative outcome. This significant increase in RT may reflect heightened self-focused attention and vigilance imposed by the upcoming social-evaluative threat. An interesting objective for subsequent investigations is to examine whether the SPN during social feedback anticipation is driven by uncertainty and/or the intrinsic motivation to be socially accepted, and how these processes are (differentially) modulated by FNE. Taken together, this study accentuated the importance of a temporally fine-grained electrophysiological method to assess social-evaluative information processing. Results provided novel insights into the behavioral and electrocortical correlates of social-evaluative feedback anticipation that may set the stage for future studies on delineating trait markers of social anxiety.

AUTHOR CONTRIBUTIONS

Melle J. W. Van der Molen, Michiel Westenberg, and Bregtje Gunther Moor: Conceived and designed the experiment; Eefje S. Poppelaars, Caroline T.A. Van Hartingsveldt, and Anita Harrewijn: Performed the experiments; Melle J. W. Van der Molen: Analyzed data and wrote the paper; Melle J. W. Van der Molen and Michiel Westenberg: Revised the paper.

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REFERENCES

Abraham, A., Kaufmann, C., Redlich, R., Hermann, A., Stark, R., Stevens, S., et al. (2013). Self-referential and anxiety-relevant information processing in subclinical social anxiety: an fMRI study. *Brain Imaging Behav.* 7, 35–48. doi: 10.1007/s11682-012-9188-x

Amodio, D. M., and Frith, C. D. (2006). Meeting of minds: the medial frontal cortex and social cognition. *Nat. Rev. Neurosci.* 7, 268–277. doi: 10.1038/nrn1884

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull.* 117, 497–529. doi: 10.1037/0033-2909.117.3.497

Böcker, K. B., Baas, J. M., Kenemans, J. L., and Verbaten, M. N. (2001). Stimulus-preceding negativity induced by fear: a manifestation of affective anticipation. *Int. J. Psychophysiol.* 43, 77–90. doi: 10.1016/S0167-8760(01)00180-5

Böcker, K. B. E., and Van Boxtel, G. J. M. (1997). "Stimulus-preceding negativity: a class of anticipatory negative potentials," in *Brain and Behavior: Past, Present, and Future*, eds G. J. M. van Boxtel and K. B. E. Böcker (Tilburg: Tilburg University Press), 105–116.

Bögels, S. M., and Reith, W. (1999). Validity of two questionnaires to assess social fears: the Dutch social phobia and anxiety inventory and the fear of blushing, trembling, and sweating questionnaire. *J. Psychopathol. Behav. Assesm.* 21, 51–66. doi: 10.1023/A:1022812227606

Bradley, M. M., and Lang, P. J. (1994). Measuring emotion: the self-assessment Manikin and the semantic differential. *J. Behav. Ther. Exp. Psychiatry* 25, 49–59. doi: 10.1016/0005-7916(94)90063-9

Brühl, A. B., Herwig, U., Delsignore, A., Jäncke, L., and Rufer, M. (2013). General emotion processing in social anxiety disorder: neural issues of cognitive control. *Psychiatry Res.* 212, 108–115. doi: 10.1016/j.pscychresns.2012.05.006

Brühl, A. B., Rufer, M., Delsignore, A., Kaffenberger, T., Jäncke, L., and Herwig, U. (2011). Neural correlates of altered general emotion processing in social anxiety disorder. *Brain Res.* 1378, 72–83. doi: 10.1016/j.brainres.2010.12.084

Brunia, C. H. M., Hackley, S. A., Van Boxtel, G. J. M., Kotani, Y., and Ohgami, Y. (2011). Waiting to perceive: reward or punishment? *Clin. Neurophysiol.* 122, 858–868. doi: 10.1016/j.clinph.2010.12.039

Carleton, R. N., Collimore, K. C., McCabe, R. E., and Antony, M. M. (2011). Addressing revisions to the Brief Fear of Negative Evaluation scale: measuring fear of negative evaluation across anxiety and mood disorders. *J. Anxiety Disord.* 25, 822–828. doi: 10.1016/j.janxdis.2011.04.002

Carleton, R. N., Mccreary, D. R., Norton, P. J., and Asmundson, G. J. (2006). Brief fear of negative evaluation scale-revised. *Depress. Anxiety* 23, 297–303. doi: 10.1002/da.20142

Carver, C. S., and White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the BIS/BAS Scales. *J. Pers. Soc. Psych.* 67, 319–333. doi: 10.1037/0022-3514.67.2.319

Catena, A., Perales, J. C., Megías, A., Cándido, A., Jara, E., and Maldonado, A. (2012). The brain network of expectancy and uncertainty processing. *PLoS ONE* 7:e40252. doi: 10.1371/journal.pone.0040252

Clark, D. M., and McManus, F. (2002). Information processing in social phobia. *Biol. Psychiatry* 51, 92–100. doi: 10.1016/S0006-3223(01)01296-3

Collins, K. A., Westra, H. A., Dozois, D. J., and Stewart, S. H. (2005). The validity of the brief version of the Fear of Negative Evaluation Scale. *J. Anxiety Disord.* 19, 345–359. doi: 10.1016/j.janxdis.2004.02.003

Downey, G., and Feldman, S. I. (1996). Implications of rejection sensitivity for intimate relationships. *J. Pers. Soc. Psychol.* 70, 1327–1343. doi: 10.1037/0022-3514.70.6.1327

Etkin, A. (2010). Functional neuroanatomy of anxiety: a neural circuit perspective. *Curr. Top. Behav. Neurosci.* 2, 251–277. doi: 10.1007/7854_2009_5

Etkin, A., and Wager, T. D. (2007). Functional neuroimaging of anxiety: a meta-analysis of emotional processing in PTSD, social anxiety disorder, and specific phobia. *Am. J. Psychiatry* 164, 1476–1488. doi: 10.1176/appi.ajp.2007.07030504

Eysenck, M. W., Derakshan, N., Santos, R., and Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion* 7, 336–353. doi: 10.1037/1528-3542.7.2.336

Ferdinand, N. K., Mecklinger, A., Kray, J., and Gehring, W. J. (2012). The processing of unexpected positive response outcomes in the mediofrontal cortex. *J. Neurosci.* 32, 12087–12092. doi: 10.1523/JNEUROSCI.1410-12.2012

Gunther Moor, B. G., Crone, E. A., and Van Der Molen, M. W. (2010a). The heartbrake of social rejection: heart rate deceleration in response to unexpected peer rejection. *Psychol. Sci.* 21, 1326–1333. doi: 10.1177/0956797610379236

Gunther Moor, B. G., Van Leijenhorst, L., Rombouts, S. A. R. B., Crone, E. A., and Van Der Molen, M. W. (2010b). Do you like me? Neural correlates of social evaluation and developmental trajectories. *Soc. Neurosci.* 5, 461–482. doi: 10.1080/17470910903526155

Hepper, E. G., Hart, C. M., Gregg, A. P., and Sedikides, C. (2011). Motivated expectations of positive feedback in social interactions. *J. Soc. Psychol.* 151, 455–477. doi: 10.1080/00224545.2010.503722

Holroyd, C. B., Nieuwenhuis, S., Yeung, N., and Cohen, J. D. (2003). Errors in reward prediction are reflected in the event-related brain potential. *Neuroreport* 14, 2481–2484. doi: 10.1097/00001756-200312190-00037

Judah, M. R., Grant, D. M., Mills, A. C., and Lechner, W. V. (2013). The neural correlates of impaired attentional control in social anxiety: an ERP study of inhibition and shifting. *Emotion* 13, 1096–1106. doi: 10.1037/a0033531

Kotani, Y., and Aihara, Y. (1999). The effect of stimulus discriminability on stimulus-preceding negativities prior to instructive and feedback stimuli. *Biol. Psychol.* 50, 1–18. doi: 10.1016/S0301-0511(98)00047-7

Levinson, C. A., Rodebaugh, T. L., White, E. K., Menatti, A. R., Weeks, J. W., Iacovino, J. M., et al. (2013). Social appearance anxiety, perfectionism, and fear of negative evaluation: distinct or shared risk factors for social anxiety and eating disorders? *Appetite* 67, 125–133. doi: 10.1016/j.appet.2013.04.002

Liebowitz, M. R. (1987). Social phobia. *Mod. Probl. Pharm.* 22, 141–173.

Luck, S. J. (2005). *An Introduction to the Even-related Potential Technique.* Cambridge, MAassachusetts: The MIT Press.

Macdonald, G., and Leary, M. R. (2005). Why does social exclusion hurt? The relationship between social and physical pain. *Psychol. Bull.* 131, 202–223. doi: 10.1037/0033-2909.131.2.202

Maner, J. K., Dewall, C. N., Baumeister, R. F., and Schaller, M. (2007). Does social exclusion motivate interpersonal reconnection? Resolving the "porcupine problem." *J. Pers. Soc. Psychol.* 92, 42–55. doi: 10.1037/0022-3514.92.1.42

Mattick, R. P., and Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav. Res. Ther.* 36, 455–470. doi: 10.1016/S0005-7967(97)10031-6

Mattox, S. T., Valle-Inclan, F., and Hackley, S. A. (2006). Psychophysiological evidence for impaired reward anticipation in Parkinson's disease. *Clin. Neurophysiol.* 117, 2144–2153. doi: 10.1016/j.clinph.2006.05.026

Morrison, A. S., and Heimberg, R. G. (2013). Attentional control mediates the effect of social anxiety on positive affect. *J. Anxiety Disord.* 27, 56–67. doi: 10.1016/j.janxdis.2012.10.002

Ohgami, Y., Kotani, Y., Hiraku, S., Aihara, Y., and Ishii, M. (2004). Effects of reward and stimulus modality on stimulus-preceding negativity. *Psychophysiol.* 41, 729–738. doi: 10.1111/j.1469-8986.2004.00203.x

Ohgami, Y., Kotani, Y., Tsukamoto, T., Omura, K., Inoue, Y., Aihara, Y., et al. (2006). Effects of monetary reward and punishment on stimulus-preceding negativity. *Psychophysiology* 43, 227–236. doi: 10.1111/j.1469-8986.2006.00396.x

Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia* 9, 97–113. doi: 10.1016/0028-3932(71)90067-4

Poli, S., Sarlo, M., Bortoletto, M., Buodo, G., and Palomba, D. (2007). Stimulus-preceding negativity and heart rate changes in anticipation of affective pictures. *Int. J. Psychophysiol.* 65, 32–39. doi: 10.1016/j.ijpsycho.2007.02.008

Polich, J. (2007). Updating P300: an integrative theory of P3a and P3b. *Clin. Neurophysiol.* 118, 2128–2148. doi: 10.1016/j.clinph.2007.04.019

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/S0005-7967(97)00022-3

Rapee, R. M., and Spence, S. H. (2004). The etiology of social phobia: empirical evidence and an initial model. *Clin. Psychol. Rev.* 24, 737–767. doi: 10.1016/j.cpr.2004.06.004

Rosenberg, M. (1965). *Society and the Adolescent Self-image.* Princeton: Princeton University Press.

Rossignol, M., Campanella, S., Bissot, C., and Philippot, P. (2013). Fear of negative evaluation and attentional bias for facial expressions: an event-related study. *Brain Cogn.* 82, 344–352. doi: 10.1016/j.bandc.2013.05.008

Salemink, E., Friese, M., Drake, E., Mackintosh, B., and Hoppitt, L. (2013). Indicators of implicit and explicit social anxiety influence threat-related interpretive bias as a function of working memory capacity. *Front. Hum. Neurosci.* 7:220. doi: 10.3389/fnhum.2013.00220

Somerville, L. H., Heatherton, T. F., and Kelley, W. M. (2006). Anterior cingulate cortex responds differentially to expectancy violation and social rejection. *Nat. Neurosci.* 9, 1007–1008. doi: 10.1038/nn1728

Somerville, L. H., Kelley, W. M., and Heatherton, T. F. (2010). Self-esteem modulates medial prefrontal cortical responses to evaluative social feedback. *Cereb. Cortex* 20, 3005–3013. doi: 10.1093/cercor/bhq049

Stavropoulos, K. K., and Carver, L. J. (2013). Reward sensitivity to faces versus objects in children: an ERP study. *Soc. Cogn. Affect. Neurosci.* doi:10.1093/scan/nst149 [Epub ahead of print].

Taylor, S. E., and Brown, J. D. (1988). Illusion and well-being: a social psychological perspective on mental health. *Psychol. Bull.* 103, 193–210. doi: 10.1037/0033-2909.103.2.193

Van der Veen, F. M., Van Der Molen, M. W., Sahibdin, P. P., and Franken, I. H. (2013). The heart-break of social rejection versus the brain wave of social acceptance. *Soc. Cogn. Affect. Neurosci.* doi: 10.1093/scan/nst120 [Epub ahead of print].

Van Noordt, S. J., and Segalowitz, S. J. (2012). Performance monitoring and the medial prefrontal cortex: a review of individual differences and context effects as a window on self-regulation. *Front. Hum. Neurosci.* 6:197. doi: 10.3389/fnhum.2012.00197

Watson, D., and Friend, R. (1969). Measurement of social-evaluative anxiety. *J. Consult. Clin. Psychol.* 33, 448–457. doi: 10.1037/h0027806

Weeks, J. W., Heimberg, R. G., Fresco, D. M., Hart, T. A., Turk, C. L., Schneier, F. R., et al. (2005). Empirical validation and psychometric evaluation of the Brief Fear of Negative Evaluation Scale in patients with social anxiety disorder. *Psychol. Assess.* 17, 179–190. doi: 10.1037/1040-3590.17.2.179

Weeks, J. W., and Howell, A. N. (2012). The bivalent fear of evaluation model of social anxiety: further integrating findings on fears of positive and negative evaluation. *Cogn. Behav. Ther.* 41, 83–95. doi: 10.1080/16506073.2012.661452

Whiting, S. E., Jenkins, W. S., May, A. C., Rudy, B. M., Davis, T. E. III, and Reuther, E. T. (2013). The role of intolerance of uncertainty in social anxiety subtypes. *J. Clin. Psychol.* doi: 10.1002/jclp.22024 [Epub ahead of print].

Wieser, M. J., Pauli, P., Weyers, P., Alpers, G.W., and Muhlberger, A. (2009). Fear of negative evaluation and the hypervigilance-avoidance hypothesis: an eye-tracking study. *J. Neural Transm.* 116, 717–723. doi: 10.1007/s00702-008-0101-0

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Being "in" or "out" of the game: subjective and acoustic reactions to exclusion and popularity in social anxiety

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Social Anxiety (SA) has been shown to be associated with compensatory deficits in pro-social behavior following exclusion and with failure to capitalize on social success. We assessed the subjective and expressive responses of high ($n = 48$) and low ($n = 56$) socially anxious individuals to exclusion, acceptance, and popularity induced by a participation in an online ball-tossing game. Before the manipulation, participants read aloud neutral and command utterances. Following the manipulation, participants rated their mood and cognitions and re-read the utterances. Acoustic properties (fundamental frequency–mF0, vocal intensity) of these utterances were analyzed. We found greater differences in self-esteem between high and low socially anxious individuals following the exclusion condition, as compared to the acceptance condition. Among low socially anxious individuals, exclusion promoted increased vocal confidence, as indicated by decreased mF0 and increased vocal intensity in uttering commands; High socially anxious individuals exhibited an opposite reaction, responding to exclusion by decreased vocal confidence. Following popularity, high SA was associated with decreased enhancement in mood and self-esteem in women but not in men. Consistent with evolutionary and interpersonal accounts of SA, we highlight the importance of examining the effects of SA and gender on events indicating unambiguous and unanimous social acceptance. Examining reactivity to changes in belongingness may have important implications for understanding the core mechanisms of SA.

Keywords: social phobia, rejection, acceptance, self-esteem, dominance, social rank, acoustic analysis, voice

INTRODUCTION

Social Anxiety disorder (SAD, or social phobia) is a condition involving marked anxiety about social or performance situations in which there is a fear of embarrassing oneself under scrutiny by others (DSM-IV, American Psychiatric Association, 2000). SAD often has its onset in childhood and tends to precede most other disorders with which it is co-morbid, most notably depression (Bittner et al., 2004). SAD is associated with severe psychological, interpersonal, and professional consequences (e.g., Ruscio et al., 2008). Given these anxieties and avoidances, it is not surprising that socially anxious individuals report high levels of negative affect, and functional impairment in several life areas (Aderka et al., 2012). Unsurprisingly, SAD is also associated with lower wellbeing (Sherbourne et al., 2010) and lower levels of positive affect (e.g., Kashdan, 2007). These findings have frequently been related to the impairment in interpersonal connectedness common in SAD (e.g., Gilboa-Schechtman et al., 2013a,b).

Most theoretical models of social anxiety (SA) consider heightened sensitivity, enhanced responsivity, and impaired affective regulation in the face of social threat to be at the epicenter of this condition (e.g., Clark and Wells, 1995; Rapee and Heimberg, 1997; Gilbert and Trower, 2001; Hofmann et al., 2004). During human evolutionary history, loss of belongingness was associated with threat to survival (Wesselmann et al., 2012a,b). Accordingly, the human tendency to belong and affiliate is frequently defined as one of the most essential and fundamental needs (e.g., Baumeister and Leary, 1995). Given the centrality of belongingness, basic psychological systems are postulated to monitor for changes in social inclusion and exclusion. Sensitivity to changes in belongingness is frequently explained in evolutionary terms: being a member of a group improves survival chances due to the protection and resources offered by the group (Lancaster, 1986). Relatedly, positive affect experienced in response to social acceptance is likely to strengthen one's psychological resilience (Fredrickson et al., 2003), to promote physical health (e.g., Davidson et al., 2010; Boehm and Kubzansky, 2012), and to increase longevity (Xu and Roberts, 2010).

Consistent with these theoretical postulations, social exclusion has been found to provoke significant changes across multiple psychobiosocial domains. It has been found to engender subjective experience of distress (Van Beest and Williams, 2006), behavioral dysregulation (Oaten et al., 2008), changes in cognitive efficiency (Hess and Pickett, 2010), changes in attentional focus (Dewall et al., 2009), enhanced blood pressure (Stroud et al., 2000), cortisol reactivity (Blackhart et al., 2007) and enhanced activation in brain regions that process and regulate the unpleasantness of physical pain (Eisenberger et al., 2003). The salubrious effects of social acceptance are also robust. Social acceptance is associated with changes in mood, self-esteem, behavior and physiology (e.g., Leary et al., 2001; Mendes et al., 2008; DeWall et al., 2010). Yet, given the centrality of the belongingness system, its implications to psychopathology in general, and to SA in particular, have not been thoroughly explored. This is the main theme of the present research.

SA is postulated to function as a warning system that alerts people to potential threats to their belongingness status (Leary and Kowalski, 1995; DeWall et al., 2011). Indeed, it has been found that socially anxious individuals are characterized by a high sensitivity to exclusion (Zadro et al., 2006). Specifically, Zadro and her colleagues found SA to be associated with more prolonged recovery following an exclusion manipulation. Using a similar exclusion paradigm, Oaten and colleagues found that individuals with high SA differ from individuals with low SA in their ability to self-regulate following exclusion (Oaten et al., 2008). Further, research in temperamentally shy children found more intense emotional upheaval and poorer vagal regulation in response to peer rejection (Gazelle and Druhen, 2009). Moreover, in a recent study with children, Reijntjes and colleagues found that SA was associated with greater changes in state self-esteem following peer disapproval (Reijntjes et al., 2011).

It appears that SA affects not only the quantitative, but also qualitative nature of coping with exclusion. While among low-socially anxious individuals exclusion promoted renewed interest in connecting with sources of positive social interaction, high-socially anxious individuals failed to react to rejection in a prosocial manner and exhibited evidence of decreased social interaction effectiveness (Mallott et al., 2009). Specifically, Mallott and colleagues examined nonverbal characteristics of self-presentation of individuals high and low in SA following interpersonal rejection. They found that, observers' subjective ratings of vocal and eye-gaze performance was inversely related to SA. In the present study we sought to extend the investigation of the effects of changes in social belongingness, to include objective measures of vocal production. Acoustic analysis of speech is emerging as an indirect, noninvasive, and sensitive measure of emotional state (Elfenbein and Ambady, 2002; Juslin and Laukka, 2004) and interpersonal strategies (Bugental et al., 2009), in research as well as in clinical settings (Diamond et al., 2010).

Vocal parameters have been examined in an attempt to capture the emotional "tone" of the voice—that is the aspect of speech that is not conveyed through the meaning of verbal utterance. These nonverbal features of a spoken message (Tusing and Dillard, 2000) have been shown to play an important role in conveying emotions (Laukka and Elfenbein, 2011) and in conducting power negotiation (Scherer, 1986; Scherer et al., 2003). Vocal parameters are less controllable than are other types of nonverbal behaviors (Zuckerman et al., 1981) and therefore may serve as "honest signals" of the speaker's current emotional state (Bugental et al., 2009). The vocal parameters that have been most frequently used in past research are fundamental frequency (mF0) and vocal intensity.

There is a robust line of research linking certain parameters of vocalization to social rank. Consistent with Ohala's (1982) evolutionary model, lower mF0 has been associated with enhanced dominance (e.g., Ohala, 1984; Puts et al., 2006, 2007; Jones et al., 2010). Vocal intensity is positively associated with dominance rating in the production of spontaneous speech (Tusing and Dillard, 2000). Moreover, these parameters were also shown to differentiate between vocal profiles of different intents (Galili et al., 2013). Specifically, as compared to neutral utterances, command utterances were characterized by increased mF0 and higher vocal intensity. Acoustic analysis has the potential to offer a subtle understanding of the ways in which individuals negotiate interpersonal interactions. Yet, acoustic analysis has, until recently, been under-utilized. We believe it offers a way to understand corrective actions people take following exclusion.

Measures of acoustic production show promise as indirect measures of SA (e.g., Laukka et al., 2008; Weeks et al., 2011, 2012; Galili et al., 2013). Specifically, analyzing the vocal properties of planned speech, we found that SA was associated with higher mF0, and with decreased vocal intensity in men (Galili et al., 2013). Using spontaneous speech, Weeks and colleagues similarly found that clinical SA was associated with increased F0, and that this pattern was more pronounced in men than in women (Weeks et al., 2012). In addition, Laukka and colleagues found that among clinically socially anxious individual mF0 was decreased among treatment responders (Laukka et al., 2008). In view of these findings, the primary aim of the present study was to extend the research on reactivity to social exclusion in SA by including acoustic indices of interpersonally-directed utterances.

The second aim of this study was to examine the reactions of socially anxious individuals to events connoting social acceptance. While those events are commonly experienced as positive by nonsocially anxious individuals, this is not necessarily the case for socially anxious persons (e.g., Weeks and Howell, 2012). Several perspectives (e.g., Alden and Taylor, 2004; Weeks and Howell, 2012; Gilboa-Schechtman et al., 2013a,b) converge in suggesting that socially anxious individuals may exhibit biased processing of positive social attention. There is growing evidence indicating that socially anxious people were less successful at capitalizing on positive social experiences than are individuals without SA, even after controlling for depression (e.g., Gilboa-Schechtman et al., 2000; Kashdan et al., 2011; see also Gilboa-Schechtman et al., 2013a,b, for review). Exploring the nature of socially anxious individuals' reactions to events indicating social acceptance is likely to contribute to the greater understanding of core processes in SA.

The experimental research on the effects of positive social attention in SA has been limited. In a pioneering study, Alden and colleagues found that, upon receiving positive feedback following a social interaction, individuals with high levels of SA expected to experience greater levels of anxiety regarding a future social interaction (Alden et al., 2004). In addition, following the receipt of positive feedback, people with high levels of SA predicted that their partner would expect more from them in the next interaction, and that they would fall short of those expectations (Alden and Wallace, 1995; Wallace and Alden, 1997). Finally, Alden and colleagues found that the tendency to interpret positive social events as indicative of negative future outcomes partially mediated the relationship between SA and decreased positive affect (Alden et al., 2008). Importantly, in all of these studies success in a given interaction was found to bear on future interaction. But what if the "beam of social attention" was not specifically related to future occurrences? Does social visibility exert a "warm glow" for socially anxious and nonsocially anxious people alike? Addressing this question was the second aim of our study.

In the present study we assessed the subjective and expressive responses of individuals high and low in SA to exclusion, acceptance, and popularity induced by a participation in an online ball-tossing paradigm—Cyberball. Cyberball is one of the most commonly used procedures in investigating the effects of social exclusion (Williams, 1997, 2001, 2009). Previous Cyberball studies included two conditions: exclusion vs. acceptance (i.e., receiving a "fair share" of the throws). In the present study we introduced a third condition—popularity—in which participants received all the possible throws from the other two players.

Before beginning the Cyberball task, participants read aloud neutral, command and request utterances. Upon completing the Cyberball task, participants rated their mood and cognitions and re-read aloud the utterances. Subjective, cognitive, and acoustic measures (mF0, vocal intensity) were analyzed.

Four hypotheses were examined. First, consistent with the enhanced exclusion-reactivity accounts, we postulated that as compared to low SA individuals, individuals high in SA would report lower mood and self-esteem following exclusion as compared to acceptance (enhanced exclusion reactivity hypothesis). Second, consistent with the impaired positivity account (Gilboa-Schechtman et al., 2013a,b), we postulated that, as compared to individuals low in SA, individuals high in SA would report lower mood and self-esteem following popularity as compared to the acceptance condition (impaired positivity hypothesis). Third, with respect to the acoustic parameters, consistent with the compensatory deficits view of SA, we postulated that exclusion (as compared to acceptance) would lead to more insecure (and less dominant) behaviors in individuals with low levels of SA, while individuals high in SA would not exhibit this pattern. Specifically, we expected to observe a greater increase in mF0 and a greater decrease in vocal intensity for command vs. neutral sentences in individuals high in SA, as compared to individuals low in SA (vocal insecurity following exclusion hypothesis). Fourth, we also expected that following popularity, individuals high in SA would exhibit a lesser increase in a pattern of confident vocal behavior as compared to individuals low in SA. Specifically, we expected a smaller decrease in mF0 and a smaller increase in vocal intensity for command vs. neutral utterances in individuals high in SA, as compared to individuals low in SA (vocal confidence following popularity hypothesis).

METHODS

PARTICIPANTS

Hundred and four university students (58 women) took part in the study in exchange for 30 NIS (equivalent to 8 US$) or academic credit. Participants were recruited through the Bar-Ilan University Psychology Department Subject Pool, as well as from advertisements in billboards on campus and electronic forums. Before arrival to the laboratory, participants received several self-report questionnaires, including questionnaires assessing SA. Participants who scored below the accepted cut-off for clinical range or above the cut-off for diagnosis for SAD (Baer and Blais, 2010) on a self-assessment measure of SA (Fresco et al., 2001) were invited to participate in the study.

PROCEDURE

Participants were invited to take part in a study investigating individual differences in "visual perception and vocal production." Upon arrival to the laboratory and signing a consent form, participant met a confederate who was introduced as a fellow participant. Participants were introduced to the research purpose and procedure, and were photographed using a web camera for future use in the Cyberball task. Next, participants engaged in a first (pre-manipulation) vocal recording session.

Participants were then told that they will play an internet game "Cyberball" (see Williams et al., 2000) with two other students, one of whom they already met in the waiting room, and the other is waiting in an adjacent lab. Next, the experimenter made a staged phone call to the neighboring laboratory, informing that the participants (the confederate and the actual participant) are ready to start. Participants were randomly assigned to one of three conditions in the ball-tossing game: Exclusion, Acceptance, and Popularity. In all conditions, the game lasted approximately 5 min.

Upon completion of the game, participants filled out the Basic Needs Threat Questionnaire (Zadro et al., 2004). Next, they performed the second (post-experimental) vocal recording session. Then, they took part in a brief (3 min) cognitive task not reported in the present study. All participants then completed several self-report questionnaires. Lastly, they were de-briefed by the experimenter about the real purpose of the experiment and its procedure. During the debriefing participants were interviewed about the believability of the experimental procedure. None expressed concerns or disbelief regarding the role of both co-participants.

RECORDINGS

Recording sessions were performed individually in a quiet room. The experimenter familiarized the participants with the equipment and remained present in the room during the entire recording session. During each recording session, the participants' voice was recorded while reading three different types of sentences: *neutral* ("Danny went to work with his dad" and "Chad helped us on the beach"), *request* ("Please open the window") and *command* ("Open the window immediately"). Participants were asked to read each sentence twice in a way consistent with their meaning. The sentences' order was randomized across participants. Participants' speech signals were recorded using a Sennheiser PC20 headset microphone (High Wycombe, United Kingdom). The microphone was positioned approximately 5 cm from the corner of the participant's mouth and connected directly to a desktop computer. Speech samples were recorded using the GoldWave program (Version 5.12, GoldWave, Inc., 2005), with a sampling rate set at 48 kHz (16 bit), mono channel (see Rochman and Amir, 2013 for a brief introductory tutorial on basic procedures for recording speech/voice and acquiring relevant acoustic measures).

MANIPULATION

Participants were told that they will play an internet game "Cyberball" (see Williams et al., 2000), and were asked to visualize the game in order to practice visual metallization skills.

On the computer screen, participants were presented with their own picture, as well as two other "participants" pictures (one man and one woman). When receiving the ball from one of the other two players, participants were required to indicate to whom they would like to throw the ball, by clicking on the appropriate player picture. In all conditions, the game lasted 30 ball tosses (approximately 5 min).

As already mentioned, there were three experimental conditions: Exclusion, Acceptance, and Popularity. In the Exclusion condition, the participant received three tosses (10%) in the beginning of the game. The rest of the time the tosses were interchanged between the two other presumed players while the participant was being ignored. In the Acceptance condition, the ball was passed equally frequently to all participants, resulting in the participant receiving 10 tosses (33%). In the Popularity condition the participant received 15 tosses (50%).

SELF-REPORT MEASURES

Basic needs threat questionnaire

(Zadro et al., 2006), contains 12 items assessing the effect of the game: *belonging* (e.g., "I felt like an outsider during the Cyberball game"), *control* (e.g., "I felt that I was able to throw the ball as often as I wanted during the game"), *self-esteem* (e.g., "I felt somewhat inadequate during the Cyberball game"), and *meaningful existence* (e.g., "I felt nonexistent during the Cyberball game"). All items are rated on a 5-point scale.

Consistent with previous research, the internal consistency of the need scale as a whole was very high ($\alpha = 0.93$) (see Williams et al., 2000; Zadro et al., 2006). Additionally, the sub-scales of belongingness, control, self-esteem, and meaningful existence also exhibited adequate-to-high internal consistencies (alphas were 0.65; 0.85; 0.85; 0.77 respectively).

The questionnaire also contained two additional items regarding the "task" (e.g., "What percent of the throws were thrown to you?", "To what extent were you included by the other participants during the game?"), and two 9-point bipolar scales assessing current mood ("negative/positive") and feelings of rejection during the game ("accepted/rejected").

Liebowitz SA Scale-Self-Report

(LSAS-SR; Fresco et al., 2001), a 24-item self-report questionnaire measuring anxiety and avoidance in social or performance situations on a 0–3 scale. The LSAS-SR has been shown to have high internal consistency, strong convergent and discriminate validity, and high test-retest reliability (Baker et al., 2002; Fresco et al., 2001). In the present study, a Cronbach's α of 0.93 was obtained for the anxiety subscale and 0.90 for the avoidance subscale.

Beck Depression Inventory

(BDI; Beck et al., 1996), a 21-item, multiple-choice, self-report questionnaire that assesses affective, cognitive, motivational and somatic symptoms of depression. In the present study we obtained a Cronbach's α of 0.81 for this measure.

ACOUSTIC MEASURES

Mean Fundamental Frequency (mF0) represents the rate of vibration of the vocal folds during phonation and speech. It is measured in Hz, and it is subjectively perceived as pitch. Men and women differ widely in mF0s, which is estimated to average around 220 Hz for women and 130 Hz for men in general (Peterson and Barney, 1952), as well as among Hebrew speakers (Most et al., 2000).

Vocal intensity reflects the amount of acoustic/vocal energy produced by the speaker and could be related to the effort used by the speaker to produce speech (Laukka et al., 2008). It is measured in decibels (dB), and it is subjectively perceived as loudness.

RESULTS

PARTICIPANTS' CHARACTERISTICS

Table 1 presents means and standard deviations (in parentheses) of participants' characteristics. Participants ($n = 104$, 58 women) ranged in age from 17 to 35, with a mean age of 23.41 years ($SD = 3.13$). Participants' level of education ranged from 12 to 18 years, with a mean of 13.17 ($SD = 1.54$). Participants LSAS scores ranged from 0 to 123 with a mean

Table 1 | Means and standard deviation (in parentheses) of participants' characteristics in the exclusion, acceptance, and popularity conditions according to social anxiety (SA) group.

	Exclusion		Acceptance		Popularity	
	High SA N = 16	Low SA N = 19	High SA N = 17	Low SA N = 16	High SA N = 15	Low SA N = 21
Age	24.37_a	25.08_a	23.00_a	23.13_a	22.60_a	22.31_a
	(4.30)	(3.89)	(2.03)	(2.33)	(1.8)	(2.79)
LSAS	63.50_a	21.26_b	52.18_a	25.31_b	57.00_a	25.48_b
	(19.55)	(10.62)	(8.29)	(10.55)	(16.66)	(10.06)
BFNE	18.06_a	10.53_b	14.94_a	12.13_a	19.33_a	10.19_b
	(9.18)	(6.68)	(7.37)	(6.6)	(7.04)	(5.72)
BDI	11.13_a	4.00_b	6.88_a	5.81_a	9.20_a	3.71_b
	(6.18)	(3.28)	(4.08)	(4.45)	(7.23)	(3.73)
% Throws	6.69_a	6.89_a	29.53_a	28.41_a	53.67_a	50.29_a
	(4.08)	(3.13)	(5.39)	(4.84)	(13.42)	(11.23)
Exclusion	4.19_a	3.84_a	1.24_a	1.38_a	1.070_a	1.05_a
	(0.65)	(0.96)	(0.44)	(0.62)	(0.26)	(0.22)
Ignore	4.31_a	4.00_a	1.35_a	1.19_a	1.07_a	1.00_a
	(0.60)	(0.94)	(0.49)	(0.40)	(0.26)	(0.00)
Mood	5.06_a	6.53_b	7.24_a	7.63_a	7.07_a	7.67_a
	(1.84)	(1.61)	(1.35)	(1.09)	(0.80)	(1.35)
Belonging	1.65_a	1.88_a	3.12_a	3.33_a	3.98_a	3.78_a
	(0.67)	(0.59)	(0.64)	(0.74)	(0.55)	(0.82)
Control	1.83_a	2.39_b	3.84_a	4.02_a	4.29_a	4.21_a
	(0.68)	(0.78)	(0.68)	(0.41)	(0.45)	(0.64)
Self-esteem	2.21_a	3.30_b	4.25_a	4.39_a	3.88_a	4.57_b
	(0.88)	(0.74)	(0.58)	(0.53)	(0.58)	(0.38)
Meaningful	1.97_a	2.54_b	4.14	4.27_a	3.96_a	4.35_b
existence	(0.54)	(0.71)	(0.69)	(0.42)	(0.77)	(0.40)
Fundamental	1.92_a	2.53_b	3.84_a	4.00_a	4.02_a	4.23_a
needs	(0.54)	(0.52)	(0.41)	(0.36)	(00.48)	(0.31)
% Women	62.5_a	31.60_a	70.60_a	62.50_a	60.00_a	52.40_a

Different subscripts (i.e., a, b) within each pair represent differences at 0.05 level, and identical subscripts(a, a) represent a lack of statistically significant difference.

score of 39.44 ($SD = 21.28$), and BDI scores ranged from 0 to 28 with a mean score of 6.54 ($SD = 5.47$). Participants were divided to high vs. low SA groups (HSA and LSA respectively) based on median split of LSAS at the time of the experiment. The mean LSAS score in the LSA group was 24 ($SD = 10.39$) and the mean LSAS score in the HSA group was 57.46 ($SD = 15.83$).

MANIPULATION CHECKS

In order to assess whether participants correctly perceived the number of throws they received, we conducted a Three-Way ANOVA with 3 (Condition: Exclusion, Acceptance, Popularity) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women). The analysis revealed the expected main effect of Condition, [$F_{(2, 91)} = 250.32$, $p < 0.001$, $\eta^2 = 0.85$]. No other main effects or interactions were found (all $ps > 0.36$). Thus, it is concluded that participants correctly perceived whether they were excluded, accepted, or made popular in the game. Moreover, SA group did not affect the correct estimation of perceived tosses [$F_{(1, 91)} = 0.62$, $p = 0.43$].

In order to assess whether participants correctly labeled their experiences, we conducted a Three-Way MANOVA on exclusion, ignoring, and acceptance ratings, with 3 (Condition: Exclusion, Acceptance, Popularity) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women) as between-subject variables. The analysis revealed the expected main effect of Condition, [Wilks' Lambda $F_{(6, 178)} = 59.53$, $p < 0.001$, $\eta^2 = 0.67$]. No other main effects or interactions were found (all $ps > 0.93$).

SUBJECTIVE SELF-REPORT

In the examination of the exclusion reactivity hypothesis and the impaired positivity hypothesis we included BDI as a covariate, as it was significantly related to measures of interest ($r > -0.19$, $p = 0.05$). Participant's subjective self-report measures according to Condition, SA group and Gender are presented in **Figure 1**.

The enhanced exclusion reactivity hypothesis

To test this hypothesis we first conducted an ANCOVA on mood ratings with 2 (Condition: Exclusion, Acceptance) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women) as between-subject variables, and BDI as a covariate. A main effect of Condition was found, such that participants in the Exclusion condition reported lower mood as compared to the participants in the Acceptance condition [$F_{(1, 59)} = 14.78$, $p < 0.001$, $\eta^2 = 0.20$]. A main effect of Group was found, such that individuals in the HSA group reported lower mood than did individuals in the LSA group [$F_{(1, 59)} = 5.69$, $p < 0.02$, $\eta^2 = 0.08$]. The effect for Gender approached significance, such that women reported lower mood than did men [$F_{(1, 59)} = 3.39$, $p = 0.07$, $\eta^2 = 0.05$]. Inconsistent with our hypothesis, no Group × Condition interaction was found [$F_{(1, 59)} = 1.18$, $p = 0.28$]. No other main effects or interactions approached significance (all $ps > 0.28$).

Next, we conducted a MANCOVA on fundamental needs scales (i.e., belongingness, control, self-esteem, and life meaning), with 2 (Condition: Exclusion, Acceptance) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women) as between-subject variables, and BDI as a covariate. A main effect of Condition was found, such that participants in the Exclusion condition reported having lower needs scores (i.e., more need-threat) than did participants in the Acceptance condition [$F_{(4, 56)} = 47.84$, $p < 0.001$, $\eta^2 = 0.77$]. Moreover, the effect of Group approached significance, [$F_{(4, 56)} = 2.32$, $p = 0.068$, $\eta^2 = 0.14$], such that individuals with HSA tended to have lower needs scores than individuals with LSA. Finally, a Condition × Gender interaction was found, such that the difference in needs scores following Exclusion vs. Acceptance in women was greater than this difference among men [$F_{(4, 56)} = 2.88$, $p < 0.03$, $\eta^2 = 0.17$]. In addition, consistent with our prediction, we found that, as compared to individuals with LSA, individuals with HSA reported lower self-esteem scores following Exclusion, as compared to the Acceptance conditions [$F_{(1, 59)} = 4.84$, $p < 0.03$, $\eta^2 = 0.09$]. No other main effects or interactions approached significance (all $ps > 0.27$).

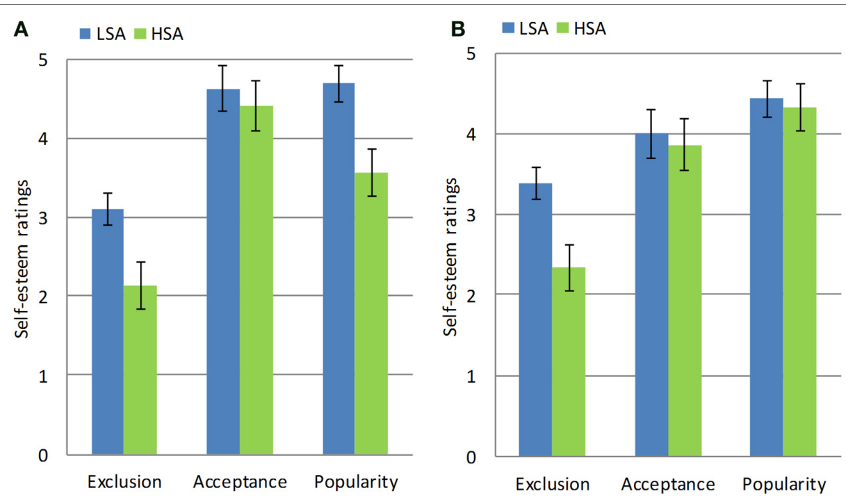

FIGURE 1 | Self-esteem measures of women (A) and men (B) in the high and low social anxiety groups following exclusion, acceptance, and popularity manipulations. Error bars represent standard errors of the mean.

The impaired positivity hypothesis

In order to examine this hypothesis, we first conducted an ANCOVA on mood ratings, with 2 (Condition: Popularity, Acceptance) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women) as between-subject variables, and BDI as a covariate. No main effect of Condition was found [$F_{(1, 60)} = 0.3$, $p = 0.59$]. A main effect of BDI was found, such that higher depression was associated with lower mood [$F_{(1, 60)} = 4.02$, $p < 0.05$, $\eta^2 = 0.06$]. A Condition × Gender interaction approached significance [$F_{(1, 60)} = 3.86$, $p = 0.054$, $\eta^2 = 0.06$]. Importantly, this Two-Way interaction was modified by a three way interaction between Condition, Gender and Group [$F_{(1, 60)} = 5.69$, $p < 0.02$, $\eta^2 = 0.08$]. We examined the differences for men and women separately. Men with HSA tended to report *higher* mood ratings following Popularity compared to Acceptance. At the same time, men with LSA did not evidence any difference in mood between the conditions [$F_{(1, 22)} = 2.36$, $p = 0.14$]. In contrast, women with HSA tended to report *lower* mood ratings following Popularity as compared to Acceptance while LSA women did not evidence any difference in mood between the conditions [$F_{(1, 37)} = 2.85$, $p = 0.1$]. In other words, the impaired positivity hypothesis was supported for women only, while men with HSA appeared to exhibit enhanced affective reactivity to Popularity. No other main effects or interactions were significant (all *ps* > 0.23).

Next, we conducted a MANCOVA on fundamental needs scales, with 2 (Condition: Popularity, Acceptance) × 2 (Group: HSA, LSA) × 2 (Gender: Men, Women) as between-subject variables, and BDI as a covariate. A main effect of Condition was found, such that participants in the Popularity condition reported having higher needs scores (i.e., less need-threat) than did participants in the Acceptance condition [$F_{(4, 57)} = 4.57$, $p < 0.003$, $\eta^2 = 0.24$]. Moreover, a significant effect of Group was found, such that individuals with HSA tended to have lower needs scores than individuals with LSA [$F_{(4, 57)} = 2.66$, $p < 0.04$, $\eta^2 = 0.16$]. Finally, a Condition × Gender interaction was found, such that the differences in needs scores for women in the Popularity vs. Acceptance condition were smaller than they were for men [$F_{(4, 57)} = 3.38$, $p < 0.01$, $\eta^2 = 0.19$].

An examination of the effects of the Self-esteem needs did not identify the predicted Group × Condition interaction [$F_{(1, 60)} = 2.78$, $p = 0.1$]. However, a Three-Way Group × Condition × Gender interaction was found [$F_{(1, 60)} = 4.54$, $p < 0.04$, $\eta^2 = 0.07$]. We examined the differences for men and women separately. Men with both high and low SA level tended to report higher self-esteem ratings following Popularity as compared to Acceptance [$F_{(4, 19)} = 2.59$, $p = 0.07$]. Women in the HSA group reported lower self-esteem rating following Popularity as compared to Acceptance, while women in the LSA group did not evidence any difference in self-esteem between the conditions [$F_{(4, 34)} = 5.53$, $p < 0.002$, $\eta^2 = 0.41$]. Again, the impaired positivity hypothesis was supported for women, but not for men. No other main effects or interactions were significant (all *ps* > 0.23).

ACOUSTIC MEASURES

Acoustic analyses were performed using Praat©software (Version 4.1.2, Boersma and Weenink, 2009). Two parameters were extracted (a) mF0: mean fundamental frequency; and (b) Vocal intensity: mean speech vocal intensity. Only command and neutral utterances were analyzed, as we did not generate specific predictions for the request utterances. In light of our hypotheses, we focused on the main effect and interactions involving Group.

For each acoustic parameter, outliers of more than three standard deviations above or below the mean were excluded from the analysis (as in Weeks et al., 2011). Means and standard deviation for each parameter in each Sentence-type and Gender are presented in **Table 2**. Because there was no correlation between BDI and mF0 or vocal intensity, BDI was not included in the analyses.

Vocal insecurity following exclusion hypothesis

In order to test this hypothesis, we conducted two separate repeated measures analyses on mF0 and vocal intensity. To this end, a difference score between the pre- and post-manipulation measurement was computed for each participant in the Exclusion condition for mF0 and vocal intensity of command and neutral utterances. Changes in acoustic parameters following Exclusion according to SA group and Gender are presented in **Figures 2**, **3**.

First, an ANOVA on mF0 was conducted with Gender (Men, Women) and Group (LSA, HSA) as between-subject variables, and Sentence-type (Neutral, Command) as a within-subject variable. A significant main effect of Group was found, such that overall, individuals with LSA exhibited a decrease in mF0 compared to individuals with HSA, for whom mF0 increased [$F_{(1, 31)} = 13.26$, $p < 0.001$, $\eta^2 = 0.30$]. Importantly, and consistent with our hypothesis, this main effect was modified by a significant Sentence-type × Group interaction, such that only individuals with LSA lowered their mF0 from neutral to command sentences [$F_{(1, 31)} = 17.33$, $p < 0.001$, $\eta^2 = 0.36$]. Because of the significant differences in mF0 between men and women, we examined these findings separately for each gender. Results confirmed that this interaction was significant for both men [$F_{(1, 17)} = 13.23$, $p < 0.002$, $\eta^2 = 0.44$] and women [$F_{(1, 14)} = 5.95$, $p < 0.03$, $\eta^2 = 0.30$].

Then, a similar ANOVA was conducted for the vocal intensity measure. A significant Three-Way Sentence-type × Gender × Group interaction was found [$F_{(1, 30)} = 6.93$, $p < 0.001$, $\eta^2 = 0.19$]. Consistent with our hypothesis, LSA men increased their vocal intensity, while HSA men decreased their vocal intensity in command utterances, as compared to neutral sentences [$F_{(1, 16)} = 7.26$, $p < 0.02$, $\eta^2 = 0.31$]. In contrast, both HSA and LSA women exhibited a greater increase in vocal intensity for command sentences as compared to neutral sentences [$F_{(1, 14)} = 4.6$, $p < 0.05$, $\eta^2 = 0.25$].

Vocal confidence following popularity hypothesis

In order to test this hypothesis, we conducted two separate repeated measures analyses on mF0 and vocal intensity. Similarly to the Exclusion condition, we used the difference score between the pre- and post-Popularity measures in acoustic parameters (mF0, vocal intensity) for command and neutral utterances.

An ANOVA on mF0 was conducted with Gender (Men, Women) and Group (LSA, HSA) as between-subject variables, and Sentence-type (Neutral, Command) as a within-subject

Table 2 | Means and standard deviation (in parentheses) of acoustic parameters recorded after exclusion and popularity conditions according to social anxiety (SA) group and gender.

	Low SA			High SA		
	T1	T2	Change	T1	T2	Change
EXCLUSION CONDITION						
Neutral sentences						
mF0 (M)	123.23 (5.42)	122.12 (5.3)	−0.53 (2.01)	143.86 (7.98)	146.77 (7.79)	1.83 (2.99)
mF0 (W)	192.33 (7.98)	191.06 (7.79)	−1.27 (2.73)	208.69 (6.18)	209.89 (6.04)	0.08 (2.23)
Vocal intensity (M)	72.34 (1.28)	70.89 (1.14)	−1.87 (1.68)	69.16 (1.89)	69.55 (1.69)	0.65 (2.48)
Vocal intensity (W)	70.87 (1.89)	68.73 (1.69)	−2.14 (2.27)	70.03 (1.46)	66.47 (1.31)	−3.33 (1.85)
Command sentences						
mF0 (M)	150.4 (6.78)	140.25 (6.77)	−9.57 (3.37)	162.42 (9.99)	168.89 (9.96)	7.83 (5.00)
mF0 (W)	228.76 (9.99)	214.5 (9.96)	−14.26 (4.56)	234.61 (7.74)	235.12 (7.72)	−1.22 (3.73)
Vocal intensity (M)	76.89 (1.42)	72.92 (1.22)	4.03 (1.27)	71.1 (2.09)	75.74 (1.79)	−4.89 (1.89)
Vocal intensity (W)	75 (2.09)	75.02 (1.79)	−0.02 (1.72)	72.76 (1.62)	71.15 (1.39)	1.53 (1.41)
Request sentences						
mF0 (M)	130.32 (5.98)	130.9 (5.92)	0.73 (3.19)	149.85 (8.8)	157.62 (8.71)	11.48 (4.74)
mF0 (W)	207.89 (8.8)	204.15 (8.71)	−3.74 (4.32)	220.6 (6.82)	212.06 (6.75)	−7.44 (3.53)
Vocal intensity (M)	70.24 (1.38)	69.38 (1.2)	−1.34 (1.50)	66.4 (2.036)	72.34 (1.769)	7.38 (2.23)
Vocal intensity (W)	70.15 (2.04)	71.06 (1.77)	0.91 (2.04)	67.37 (1.58)	66.51 (1.47)	−0.97 (1.66)
POPULARITY CONDITION						
Neutral sentences						
mF0 (M)	114.18 (6.18)	115.74 (6.04)	1.16 (2.36)	121.8 (7.979)	124.38 (7.79)	1.32 (2.99)
mF0 (W)	196.58 (5.89)	198.16 (5.76)	1.58 (2.01)	194.24 (6.91)	198.78 (6.75)	4.54 (2.36)
Vocal intensity (M)	69.32 (1.46)	71.1 (1.31)	−0.23 (1.96)	70.52 (1.89)	69.5 (1.69)	3.02 (2.448)
Vocal intensity (W)	68.76 (1.4)	69.19 (1.24)	0.43 (1.68)	69.72 (1.54)	69.68 (1.38)	0.41 (1.96)
Command sentences						
mF0 (M)	129.09 (7.74)	128.98 (7.72)	−1.10 (3.95)	143.91 (9.99)	147.63 (9.96)	3.16 (5.00)
mF0 (W)	215.09 (7.38)	212.28 (7.36)	−2.80 (3.37)	229.91 (8.65)	226.22 (8.63)	−3.69 (3.95)
Vocal intensity (M)	72.37 (1.62)	71.87 (1.39)	0.44 (1.49)	74.91 (2.09)	76.26 (1.79)	1.24 (1.89)
Vocal intensity (W)	72.72 (1.55)	71.1 (1.32)	1.62 (1.27)	74.35 (1.71)	71.95 (1.46)	2.34 (1.49)
Request sentences						
mF0 (M)	125.82 (6.82)	119.86 (6.75)	−2.74 (3.74)	128.93 (8.8)	134.22 (8.71)	6.12 (4.74)
mF0 (W)	202.36 (6.5)	202.89 (6.43)	0.54 (3.19)	207.24 (7.62)	210.59 (7.54)	3.34 (3.74)
Vocal intensity (M)	68.01 (1.58)	67.18 (1.37)	−2.34 (1.76)	68.12 (2.04)	69.31 (1.77)	1.27 (2.23)
Vocal intensity (W)	68.43 (1.5)	67.76 (1.31)	−0.67 (1.50)	69.08 (1.66)	68.59 (1.44)	−0.26 (1.76)

variable. No significant effects or interactions were identified (all $ps > 0.13$). A similar ANOVA was conducted on the vocal intensity measures, with no significant main effects or interactions (all $ps > 0.25$).

DISCUSSION

The present study examined reactivity to changes in belongingness based on subjective and expressive (implicit) measures in individuals high and low on a self-report measure of SA. First, our exclusion-reactivity hypothesis was partially supported. Our results support previous findings that threat to belongingness has a general negative effect on individuals, but that, on most measures, the immediate effect of exclusion is not associated with individual differences (Zadro et al., 2006; Oaten et al., 2008; Williams, 2009; but see also Wesselmann et al., 2012a,b). Specifically, we did not find that individuals with HSA reported lower mood or higher threat of their fundamental needs following exclusion (as compared to acceptance), as compared to individuals with LSA. However, consistent with our hypothesis, we found that, as compared to individuals with LSA, individuals with HSA were more affected by exclusion (than acceptance) condition on measures assessing self-esteem. Importantly, these findings held while controlling for significant effects of depressive symptoms severity. Thus, while there were no differences in the way that HSA and LSA individuals perceived the reality of the interaction (i.e., both groups estimated number of throws equally accurately), HSA individuals reported lower self-esteem following exclusion than following acceptance than did LSA individuals. These results

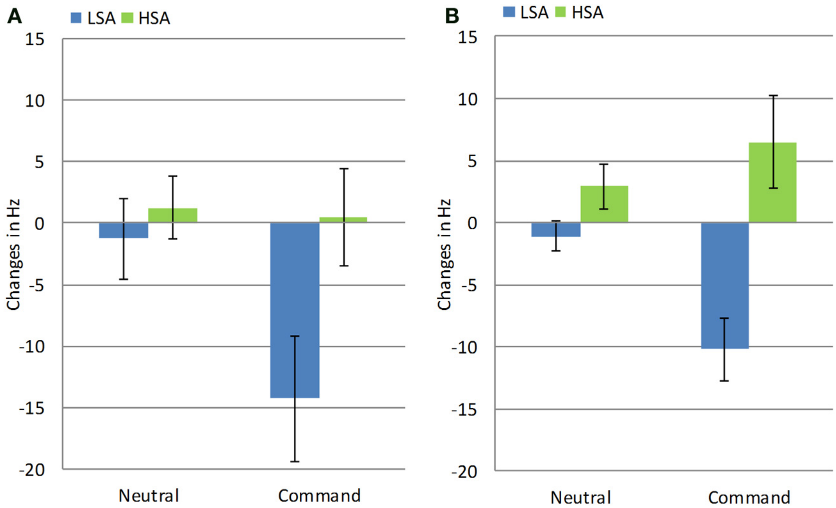

FIGURE 2 | Changes in mF0 following exclusion in high and low socially anxious women (A) and men (B). Error bars represent standard errors of the mean.

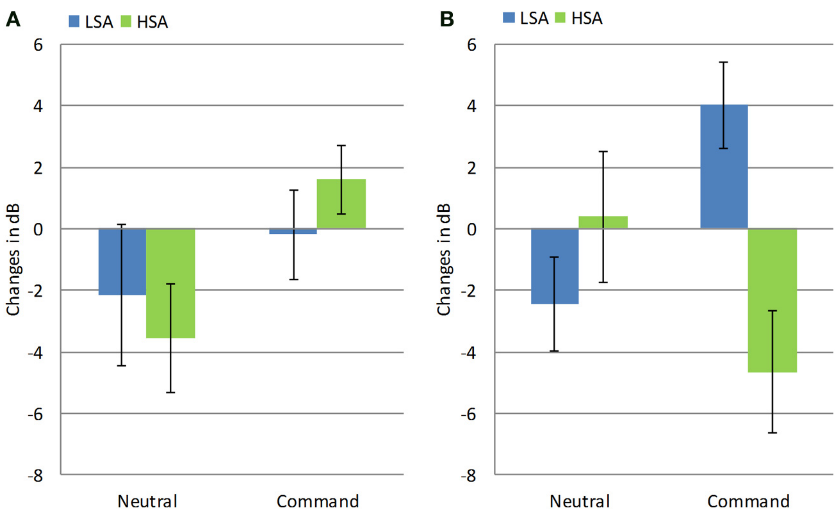

FIGURE 3 | Changes in vocal intensity following exclusion in high and low socially anxious women (A) and men (B). Error bars represent standard errors of the mean.

are consistent with previous findings demonstrating that SA in children was associated with greater changes in self-esteem following rejection (Reijntjes et al., 2011). Thus, the present findings are broadly consistent with Leary's view of SA as possessing an over-sensitive sociometers (e.g., Leary and Jongman-Sereno, in press).

Second, we tested the impaired positivity hypothesis, which postulated that individuals with HSA will report attenuated subjective reactions to popularity compared to acceptance. Our impaired positivity hypothesis was supported for women, but not for men. Specifically, we found that while SA did not affect men's self-esteem ratings in response to popularity as opposed to acceptance, HSA, but not LSA women, reported decreases in mood and in self-esteem. Importantly, men with HSA were found to be more affectively responsive to popularity than to acceptance as opposed to men with LSA. It appears that HSA men are more dependent on external feedback than are LSA men. These findings support and extend the research showing that gender exerts a significant effect on interpersonal relationships (e.g., Benenson, 1990; Kwang et al., 2013). Specifically, it is possible that while social visibility (being at the center) does not carry negative costs for men, such visibility may incur negative consequences for women (e.g., Cillessen and Borch, 2006). Alternatively, it is also possible that popularity in the ball-tossing game carries different (and more positive) connotations for men than for women.

Third, we postulated that individuals with HSA would exhibit a pattern of vocal insecurity following exclusion, whereas individuals with LSA would not exhibit this pattern. This hypothesis was mostly supported by our findings. Specifically, we found that HSA men exhibited an increase in mF0 and a decrease in vocal intensity in command sentences. In contrast, LSA men exhibited an opposite pattern: they evidenced a decrease in mF0 and an increase in vocal intensity. Similarly, HSA women uttered command sentences in higher mF0 than did LSA women. Taken together, these findings suggest that after experiencing exclusion, men, and to a somewhat lesser extent, women, with LSA exhibit a confident and dominant pattern of responses, while individuals with HSA exhibit an insecure pattern.

Fourth, we tested the impaired confidence hypotheses, according to which HSA individuals are expected to exhibit a less pronounced increase in vocal confidence than those with LSA after experiencing a popularity condition. This hypothesis was not supported by our data.

SOCIAL EXCLUSION: REPARATIVE REPERTOIRE

When interpersonal status-quo is threatened, due to social exclusion or rejection, the need to take reparative action arises. Such a need is likely to mobilize various subsystems, energize behavior, attune the sensitivity of the cognitive system to signals of acceptance or rejection, and influence motivation and behavior. Previous studies have documented that social exclusion may lead to distinct types of responses. These include social coldness/avoidance (e.g., DeWall and Baumeister, 2006; Twenge et al., 2007), affiliation (Maner et al., 2007; Dewall et al., 2009) and aggression (Twenge et al., 2001; DeWall et al., 2010). Insofar as acoustic parameters are seen as proxy for interpersonal strategies, our study suggests that, some individuals react to social exclusion by adopting strategies aimed for restoring social status, while others may react by "profile lowering" and utilization of behaviors typically associated with submissiveness and deference.

The interpersonal circumplex (e.g., Wiggins, 1979) conceptualizes the realm of social behaviors as consisting of two axes: dominance (i.e., power, competence, agency) and affiliation (i.e., warmth, love, communion). When examined through this prism, social exclusion can either heighten or lower the desire to affiliate, and the motivation to restore social rank. This conceptualization brings the rather disparate literature of reactions to exclusion under a unified theoretical umbrella, suggesting that exclusion (and possibly popularity) may lead to the use of strategies for increasing social rank, and not only those intended to regain social acceptance. In addition, social exclusion may lead to the simultaneous employment of several types of coping strategies, as people may increase their social visibility while also increasing the affiliative efforts on the one hand, or signal deference and social withdrawal on the other hand (see also Powers and Heatherton, 2012). Considered in concert, these findings are suggestive of the great flexibility and diversity of responses to social exclusion.

EXCLUSION AND SOCIAL ANXIETY

In this study we found that vocal characteristics of command and neutral sentences provided cues for changes in belongingness status, and that individual differences (gender, SA) modulated these effects. Specifically, we suggest that HSA individuals respond to social exclusion by using submissive tactics. These findings are in line with previous studies, which similarly found that individuals with HSA report using more submissive behaviors and endorse more submissive cognitions than individuals with LSA (Aderka et al., 2009; Weeks et al., 2011). In addition, other studies have found that individuals high in SA were rated as less dominant, and that HSA women made greater efforts to minimize interpersonal disharmony than did LSA women, by using more appeasement statements (Oakman et al., 2003).

These findings lent further support to theoretical accounts which place concerns with social rank and power at the core of SA (e.g., Gilbert, 2001; Gilbert and Trower, 2001; Mineka and Öhman, 2002; Johnson et al., 2012; Gilboa-Schechtman and Shachar-Lavie, 2013). HSA individuals opt for submissive or deferring responses when faced with social threats—either exclusion or defeat. Future studies may explore whether, and under what conditions, social exclusion/rejection in HSA individuals leads to deficits in affiliative behavior, deficits in assertive behaviors, or general social withdrawal.

Recent studies focused on the neural correlates of interpersonal exclusion in individuals with psychopathology (e.g., Maurage et al., 2012). Specifically, Maurage and colleagues found that, as compared to controls, individuals with alcohol dependence, exhibited increased activation in brain "reactivity" areas (i.e., areas usually associated with social exclusion feelings such as dorsal anterior cingulate cortex, insula) as well as decreased activation in areas associated with regulations of those feelings (e.g., middle frontal gyrus and inferior frontal gyrus). Extending these studies to examine the neural correlates of social exclusion (and possibly social rank loss) in SA may strengthen our understanding of core mechanism(s) of this disorder.

The present findings extend existing research in several ways. First, while previous research focused mostly on affiliative responses following exclusion (e.g., Maner et al., 2007; Mallott et al., 2009; Buckner et al., 2010; Tai et al., 2011), we focused on responses connoting dominance and submissiveness. Second, we examined expressive interpersonal responses. The emphasis on production, rather than perception of social signals, is essential for evaluating the impact of behaviors of socially anxious individuals on their chances of creating a supportive and respectful interaction. In addition to conveying the speaker's emotional states, vocal expressions may also serve as a signal to the listener, serving as an appeal for reaction (Laukka and Elfenbein, 2011). Such expressions modulate and coordinate interpersonal interactions. Third, we found that the pattern of affective, cognitive, and behavioral response was specific to SA, rather than emerging from concomitant depressive symptoms. This emphasizes the impaired reactions to exclusion as a core feature of SA.

POPULARITY, SOCIAL ANXIETY, AND GENDER

Evolutionary and interpersonal perspectives converge in suggesting that social stress arises in response to changes and modulation in social standing and social fortunes (e.g., Gilbert and Trower, 2001; Alden and Taylor, 2004). While research so far has focused on the examination of social threats (e.g., public speaking) and negative social events (e.g., exclusion, rejection), we examined the after-effects of exclusive social attention (popularity). Consistent with impaired positivity accounts, our findings suggest that the effects of enhanced social attention tend to be negative for women high (but not low) in SA. The mood and self-esteem of women with HSA decreased in situations of enhanced attention, compared to situations of equal attention (see also Gilboa-Schechtman et al., 2000; Gilbert and Trower, 2001; Alden et al., 2008; Weeks, 2010; Gilboa-Schechtman et al., 2013a,b). In contrast, men did not exhibit the predicted negatively biased reactivity to popularity. Instead, in that condition, men tended to exhibit an enhanced affective reactivity, supporting a high contingency of social esteem and external approval on SA (Reijntjes et al., 2011; Leary and Jongman-Sereno, in press). It is possible that, while no differences in subjective experience following exclusive social attention are reported by men high and low in SA, brain activation measures may unveil a different, more sensitive, pattern (for a similar argument, see Eisenberger and Lieberman, 2004).

LIMITATIONS AND FUTURE DIRECTIONS

Several limitations of our study should be noted. First, while the popularity condition affected the perceptions and the fundamental needs of our participants, it did not affect their mood ratings or the acoustic measures. We take these findings to mean that our popularity manipulation is a less powerful counterpart to the exclusion condition. Future research may attempt to enhance the effectiveness of popularity manipulation by using alternative procedures. Such alternatives could include the "survivor game" used by Reijntjes et al. (2011), the interpersonal rejection paradigm, as in Mallott et al. (2009), or a modification of the Cyberball procedure that would include additional participants, to enhance the difference between the acceptance and the popularity conditions. Second, we used only post-manipulation measures of mood, as typically performed in previous studies with Cyberball. Thus, we could only compare both exclusion and popularity conditions to the acceptance condition. Such comparisons are clearly less sensitive than within-subject comparisons. Future studies may use other manipulations allowing the assessment of pre- and post-mood measures. Third, our findings need to be replicated with spontaneous, rather than planned speech. Spontaneous speech is likely to involve increased task demands, as the speaker is concerned with the content of communication as well as with its manner. This may lead to greater or more pervasive disruption in vocal characteristics. Fourth, in this study we focused on a limited number of acoustic parameters. A more comprehensive examination of a wide range of expressive tactics (vocal, postural, facial) would enrich our understanding of the ways in which humans express intentions and emotions. Fifth, our sample size was rather small, likely restricting our ability to detect some individual differences. Sixth, our results need to be replicated in a clinical population. While there is considerable evidence that SA and SAD form a continuum (e.g., Ruscio, 2010; Haslam et al., 2012), it is possible that individuals with clinical levels of SA exhibit qualitatively different forms of impairment. Moreover, future studies could profit from a differentiation between the effects of social and generalized anxiety on responses to changes in belongingness. Finally, in our study we examined the effects of threats to belongingness. An extension of the present finding to other domains, such as threats to social status (e.g., winning or losing a competition), would allow a greater understanding of the response to changes in interpersonal fortunes in SA.

SUMMARY AND CONCLUSIONS

Despite these limitations, we believe that our study makes several contributions. First, we show that a brief manipulation of exclusion exerts significant and differential effects on vocal expression, which can be quantified objectively. Indeed, our study is the first to suggest that social exclusion affects expressive interpersonal signals. Second, we argue that vocal changes exhibited by highly socially anxious individuals (especially males) are related to dominance expression impairment. Taken together with previous research on vocal properties of speech in socially anxious individuals (e.g., Weeks et al., 2012; Galili et al., 2013) our data suggest that vocal parameters of speech, especially mF0, may be used as objective markers of SA. Third, our data point to the hypersensitivity of social rank biobehavioral system functioning in SA (see also Johnson et al., 2012). In fact, reactivity to changes in social fortune may emerge as a core vulnerability in SA (see also Levinson et al., 2013). Indeed, such a conceptualization of SA may inform interventions which can be designed to decrease the reactivity and increase the adaptability of socially anxious individuals' response to changes in belongingness and in social rank. Fourth, significant differences in the subjective reactions of socially anxious men and women to changes in belongingness were found. These findings are consistent with evolutionary and interpersonal accounts of SA and highlight the importance of examining the effects of SA and gender on expressive and subjective reactions to events connoting social acceptance and ascendance. The examination of SA from the perspective of basic psychological systems may offer a new, theory-based approach to the nosology and treatment of this highly prevalent anxiety disorder.

AUTHOR CONTRIBUTIONS

Eva Gilboa-Schechtman was responsible for the design of the study, supervised the running of the participants, performed the majority of data analyses, and wrote the study for publication. Lior Galili assisted in the running of the study, analysis of the vocal data and write-up. Yair Sahar assisted in data analyses and write-up. Ofer Amir supervised the vocal analysis and assisted in write-up.

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REFERENCES

Aderka, I. M., Hofmann, S. G., Nickerson, A., Hermesh, H., Gilboa-Schechtman, E., and Marom, S. (2012). Functional impairment in social anxiety disorder. *J. Anxiety Disord.* 26, 393–400. doi: 10.1016/j.janxdis.2012.01.003

Aderka, I. M., Weisman, O., Shahar, G., and Gilboa-Schechtman, E. (2009). The roles of the social rank and attachment systems in social anxiety. *Pers. Individ. Dif.* 47, 284–288. doi: 10.1016/j.paid.2009.03.014

Alden, L. E., Mellings, T. M. B., and Laposa, J. M. (2004). Framing social information and generalized social phobia. *Behav. Res. Ther*. 42, 585–600. doi: 10.1016/S0005-7967(03)00163-3

Alden, L. E., and Taylor, C. T. (2004). Interpersonal processes in social phobia. *Clin. Psychol. Rev*. 24, 857–882. doi: 10.1016/j.cpr.2004.07.006

Alden, L. E., Taylor, C. T., Mellings, T. M. J. B., and Laposa, J. M. (2008). Social anxiety and the interpretation of positive social events. *J. Anxiety Disord*. 22, 577–590. doi: 10.1016/j.janxdis.2007.05.007

Alden, L. E., and Wallace, T. (1995). Social phobia and social appraisal in successful and unsuccessful social interactions. *Behav. Res. Ther*. 33, 497–505. doi: 10.1016/0005-7967(94)00088-2

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders, 4th Edn, Text Revision*. Washington, DC: American Psychiatric Association. doi: 10.1176/appi.books.9780890423349

Baer, L., and Blais, M. A. (2010). *Handbook of Clinical Rating Scales and Assessment in Psychiatry and Mental Health In Current Clinical Psychiatry*, Vol. 21. New York: Humana Press. doi: 10.1007/978-1-59745-387-5

Baker, S. L., Heinrichs, N., Kim, H. J., and Hofmann, S. G. (2002). The Liebowitz social anxiety scale as a self-report instrument: a preliminary psychometric analysis. *Behav. Res. Ther*. 40, 701–715. doi: 10.1016/S0005-7967(01)00060-2

Baumeister, R. F., and Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychol. Bull*. 117, 497–529. doi: 10.1037/0033-2909.117.3.497

Beck, A. T., Steer, R. A., and Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio, TX: Psychological Corporation.

Benenson, J. F. (1990). Gender differences in social networks. *J. Early Adolesc*. 10, 472–495. doi: 10.1177/0272431690104004

Bittner, A., Goodwin, R. D., Wittchen, H. U., Beesdo, K., Höfler, M., and Lieb, R. (2004). What characteristics of primary anxiety disorders predict subsequent major depressive disorder? *J. Clin. Psychiatry* 65, 618–626. doi: 10.4088/JCP.v65n0505

Blackhart, G. C., Eckel, L. A., and Tice, D. M. (2007). Salivary cortisol in response to acute social rejection and acceptance by peers. *Biol. Psychol*. 75, 267–276. doi: 10.1016/j.biopsycho.2007.03.005

Boehm, J. K., and Kubzansky, L. D. (2012). The heart's content: the association between positive psychological well-being and cardiovascular health. *Psychol. Bull*. 138, 655–691. doi: 10.1037/a0027448

Boersma, P., and Weenink, D. (2009). *Praat: Doing Phonetics by Computer [Computer Program]. Version 5.1.05*. Available online at: http://www.praat.org/

Buckner, J. D., Dewall, C. N., Schmidt, N. B., and Maner, J. K. (2010). A tale of two threats: social anxiety and attention to social threat as a function of social exclusion and non-exclusion threats. *Cogn. Ther. Res*. 34, 449–455. doi: 10.1007/s10608-009-9254-x

Bugental, D. B., Beaulieu, D. A., Schwartz, A., and Dragosits, R. (2009). Domain-specific responses to power-based interaction. *J. Exp. Soc. Psychol*. 45, 386–391. doi: 10.1016/j.jesp.2008.10.005

Cillessen, A. H. N., and Borch, C. (2006). Developmental trajectories of adolescent popularity: a growth curve modelling analysis. *J. Adolesc*. 29, 935–959. doi: 10.1016/j.adolescence.2006.05.005

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Social Phobia: Diagnosis, Assessment, and Treatment*, eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope, and F. R. Schneier (New York, NY: Guilford Press), 69–93.

Davidson, K. W., Mostofsky, E., and Whang, W. (2010). Don't worry, be happy: positive affect and reduced 10-year incident coronary heart disease: the Canadian Nova Scotia Health Survey. *Eur. Heart J*. 31, 1065–1070. doi: 10.1093/eurheartj/ehp603

DeWall, C. N., and Baumeister, R. F. (2006). Alone but feeling no pain: effects of social exclusion on physical pain tolerance and pain threshold, affective forecasting, and interpersonal empathy. *J. Pers. Soc. Psychol*. 91, 1–15. doi: 10.1037/0022-3514.91.1.1

DeWall, C. N., Deckman, T., Pond, R. S., and Bonser, I. (2011). Belongingness as a core personality trait: how social exclusion influences social functioning and personality expression. *J. Pers*. 79, 1281–1314. doi: 10.1111/j.1467-6494.2010.00695.x

Dewall, C. N., Maner, J. K., and Rouby, D. A. (2009). Social exclusion and early-stage interpersonal perception: selective attention to signs of acceptance. *J. Pers. Soc. Psychol*. 96, 729–741. doi: 10.1037/a0014634

DeWall, C. N., Twenge, J. M., Bushman, B., Im, C., and Williams, K. (2010). A little acceptance goes a long way: applying social impact theory to the rejection-aggression link. *Soc. Psychol. Pers. Sci*. 1, 168–174. doi: 10.1177/1948550610361387

Diamond, G. M., Rochman, D., and Amir, O. (2010). Arousing primary vulnerable emotions in the context of unresolved anger: "Speaking about" vs. "speaking to." *J. Couns. Psychol*. 57, 402–410. doi: 10.1037/a0021115

Eisenberger, N. I., and Lieberman, M. D. (2004). Why rejection hurts: a common neural alarm system for physical and social pain. *Trends Cogn. Sci*. 8, 294–300. doi: 10.1016/j.tics.2004.05.010

Eisenberger, N. I., Lieberman, M. D., and Williams, K. D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science* 302, 290–292. doi: 10.1126/science.1089134

Elfenbein, H. A., and Ambady, N. (2002). On the universality and cultural specificity of emotion recognition: a meta-analysis. *Psychol. Bull*. 128, 203–235. doi: 10.1037/0033-2909.128.2.203

Fredrickson, B. L., Tugade, M. M., Waugh, C. E., and Larkin, G. R. (2003). What good are positive emotions in crisis? A prospective study of resilience and emotions following the terrorist attacks on the United States on September 11th, 2001. *J. Pers. Soc. Psychol*. 84, 365–376. doi: 10.1037/0022-3514.84.2.365

Fresco, D. M., Coles, M. E., Heimberg, R. G., Liebowitz, M. R., Hami, S., Stein, M. B., et al. (2001). The Liebowitz Social Anxiety Scale: a comparison of the psychometric properties of self-report and clinician-administered formats. *Psychol. Med*. 31, 1025–1035. doi: 10.1017/S0033291701004056

Galili, L., Amir, O., and Gilboa-Schechtman, E. (2013). Acoustic properties of dominance and request utterances in social anxiety. *J. Soc. Clin. Psychol*. 32, 651–673. doi: 10.1521/jscp.2013.32.6.651

Gazelle, H., and Druhen, M. J. (2009). Anxious solitude and peer exclusion predict social helplessness, upset affect, and vagal regulation in response to behavioral rejection by a friend. *Dev. Psychol*. 45, 1077–1096. doi: 10.1037/a0016165

Gilbert, P. (2001). Evolution and social anxiety: the role of attraction, social competition, and social hierarchies. *Psychiatr. Clin. North Am*. 24, 723–751. doi: 10.1016/S0193-953X(05)70260-4

Gilbert, P., and Trower, P. (2001). *Evolution and Process iSocial Anxiety.* New York, NY, US: John Wiley and Sons Ltd. 259–279.

Gilboa-Schechtman, E., Franklin, M. E., and Foa, E. B. (2000). Anticipated reactions to social events: differences among individuals with generalized social phobia, obsessive compulsive disorder, and nonanxious controls. *Cogn. Ther. Res*. 24, 731–746. doi: 10.1023/A:1005595513315

Gilboa-Schechtman, E., Friedman, L., Helpman, L., and Kananov, J. (2013a). Self-evaluations of social rank and affiliation in social anxiety disorder: explicit and implicit measures. *Int. J. Cogn. Ther*. 6, 208–220. doi: 10.1521/ijct.2013.6.3.208

Gilboa-Schechtman, E., and Shachar-Lavie, I. (2013). More than a face: a unified theoretical perspective on nonverbal social cue processing in social anxiety. *Front. Hum. Neurosci*. 7:904. doi: 10.3389/fnhum.2013.00904

Gilboa-Schechtman, E., Shachar, I., and Sahar, Y. (2013b). "Positivity impairment as a broad-based feature of social anxiety," in *Handbook of Social Anxiety Disorder*, ed J. Weeks (New York, NY: Wiley-Blackwell Publishing Ltd).

Haslam, N., Holland, E., and Kuppens, P. (2012). Categories vs. dimensions in personality and psychopathology: a quantitative review of taxometric research. *Psychol. Med*. 42, 903–920. doi: 10.1017/S0033291711001966

Hess, Y. D., and Pickett, C. L. (2010). Social rejection and self- vs. other-awareness. *J. Exp. Soc. Psychol*. 46, 453–456. doi: 10.1016/j.jesp.2009.12.004

Hofmann, S. G., Heinrichs, N., and Moscovitch, D. A. (2004). The nature and expression of social phobia: toward a new classification. *Clin. Psychol. Rev*. 24, 769–797. doi: 10.1016/j.cpr.2004.07.004

Johnson, S. L., Leedom, L. J., and Muhtadie, L. (2012). The dominance behavioral system and psychopathology: evidence from self-report, observational, and biological studies. *Psychol. Bull*. 138, 692–743. doi: 10.1037/a0027503

Jones, B. C., Feinberg, D. R., DeBruine, L. M., Little, A. C., and Vukovic, J. (2010). A domain-specific opposite-sex bias in human preferences for manipulated voice pitch. *Anim. Behav*. 79, 57–62. doi: 10.1016/j.anbehav.2009.10.003

Juslin, P. N., and Laukka, P. (2004). Expression, perception, and induction of musical emotions: a review and a questionnaire study of everyday listening. *J. New Music Res*. 33, 217–238. doi: 10.1080/0929821042000317813

Kashdan, T. B. (2007). Social anxiety spectrum and diminished positive experiences: theoretical synthesis and meta-analysis. *Clin. Psychol. Rev*. 27, 348–365. doi: 10.1016/j.cpr.2006.12.003

Kashdan, T. B., Weeks, J. W., and Savostyanova, A. A. (2011). Whether, how, and when social anxiety shapes positive experiences and events: a self-regulatory framework and treatment implications. *Clin. Psychol. Rev*. 31, 786–799. doi: 10.1016/j.cpr.2011.03.012

Kwang, T., Crockett, E. E., Sanchez, D. T., and Swann, W. B. (2013). Men seek social standing, women seek companionship: sex differences in deriving self-worth from relationships. *Psychol. Sci*. 24, 1142–1150. doi: 10.1177/0956797612467466

Lancaster, J. B. (1986). Primate social behavior and ostracism. *Ethol. Sociobiol*. 7, 215–225. doi: 10.1016/0162-3095(86)90049-X

Laukka, P., and Elfenbein, H. A. (2011). Emotion appraisal dimensions can be inferred from vocal expressions. *Soc. Psychol. Pers. Sci*. 3, 529–536. doi: 10.1177/1948550611428011

Laukka, P., Linnman, C., Åhs, F., Pissiota, A., Frans, Ö., Faria, V., et al. (2008). In a nervous voice: acoustic analysis and perception of anxiety in social phobics' speech. *J. Nonverbal Behav*. 32, 195–214. doi: 10.1007/s10919-008-0055-9

Leary, M. R., Cottrell, C. A., and Phillips, M. (2001). Deconfounding the effects of dominance and social acceptance on self-esteem. *J. Pers. Soc. Psychol*. 81, 898–909. doi: 10.1037/0022-3514.81.5.898

Leary, M. R., and Jongman-Sereno, K. P. (in press). "Social anxiety as an early warning system: a refinement and extension of the self-presentation theory of social anxiety," in *Social Anxiety: Clinical, Developmental, and Social Perspectives*, eds S. Hofmann and P. DiBartolo (Amsterdam: Elsevier).

Leary, M. R., and Kowalski, R. M. (1995). "The self-presentation model of social phobia," in *Social Phobia: Diagnosis, Assessment, and Treatment*, eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope, and F. R. Schneier (New York, NY: Guilford), 94–112.

Levinson, C. A., Langer, J. K., and Rodebaugh, T. L. (2013). Reactivity to exclusion prospectively predicts social anxiety symptoms in young adults. *Behav. Ther*. 44, 470–478. doi: 10.1016/j.beth.2013.04.007

Mallott, M. A., Maner, J. K., DeWall, N., and Schmidt, N. B. (2009). Compensatory deficits following rejection: the role of social anxiety in disrupting affiliative behavior. *Depress. Anxiety* 26, 438–446. doi: 10.1002/da.20555

Maner, J. K., DeWall, C. N., Baumeister, R. F., and Schaller, M. (2007). Does social exclusion motivate interpersonal reconnection? Resolving the "porcupine problem." *J. Pers. Soc. Psychol*. 92, 42–55. doi: 10.1037/0022-3514.92.1.42

Maurage, P., Joassin, F., Philippot, P., Heeren, A., Vermeulen, N., Mahau, P., et al. (2012). Disrupted regulation of social exclusion in alcohol-dependence: an fMRI study. *Neuropsychopharmacology* 37, 2067–2075. doi: 10.1038/npp.2012.54

Mendes, W. B., Major, B., McCoy, S., and Blascovich, J. (2008). How attributional ambiguity shapes physiological and emotional responses to social rejection and acceptance. *J. Pers. Soc. Psychol*. 94, 278–291. doi: 10.1037/0022-3514.94.2.278

Mineka, S., and Öhman, A. (2002). Phobias and preparedness: the selective, automatic, and encapsulated nature of fear. *Biol. Psychiatry* 52, 927–937. doi: 10.1016/S0006-3223(02)01669-4

Most, T., Amir, O., and Tobin, Y. (2000). The Hebrew vowel system: Raw and normalized acoustic data. *Lang. Speech* 43, 295–308. doi: 10.1177/00238309000430030401

Oakman, J., Gifford, S., and Chlebowsky, N. (2003). A multilevel analysis of the interpersonal behavior of socially anxious people. *J. Pers*. 71, 397–434. doi: 10.1111/1467-6494.7103006

Oaten, M., Williams, K. D., Jones, A., and Zadro, L. (2008). The effects of ostracism on self-regulation in the socially anxious. *J. Soc. Clin. Psychol*. 27, 471–504. doi: 10.1521/jscp.2008.27.5.471

Ohala, J. J. (1982). Physiological mechanisms underlying tone and intonation. In Fujisaki, Garding, Pre-prints working group on intonation (pp. 1–12). Paper presented in the13th International Congress of Linguists, Tokyo 1982.

Ohala, J. J. (1984). An ethological perspective on common cross-language utilization of F0 of voice. *Phonetica*, 41, 1–16. doi: 10.1159/000261706

Peterson, G. E., and Barney, H. L. (1952). Control methods used in a study of the vowels. *J. Acoust. Soc. Am*. 24, 175–184. doi: 10.1121/1.1906875

Powers, K. E., and Heatherton, T. F. (2012). Characterizing socially avoidant and affiliative responses to social exclusion. *Front. Integr. Neurosci*. 6:46. doi: 10.3389/fnint.2012.00046

Puts, D. A., Gaulin, S. J. C., and Verdolini, K. (2006). Dominance and the evolution of sexual dimorphism in human voice pitch. *Evol. Hum. Behav*. 27, 283–296. doi: 10.1016/j.evolhumbehav.2005.11.003

Puts, D. A., Hodges, C. R., Cárdenas, R. A., and Gaulin, S. J. C. (2007). Men's voices as dominance signals: vocal fundamental and formant frequencies influence dominance attributions among men. *Evol. Hum. Behav*. 28, 340–344. doi: 10.1016/j.evolhumbehav.2007.05.002

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther*. 35, 741–756. doi: 10.1016/S0005-7967(97)00022-3

Reijntjes, A., Thomaes, S., Boelen, P., van der Schoot, M., de Castro, B. O., and Telch, M. J. (2011). Delighted when approved by others, to pieces when rejected: children's social anxiety magnifies the linkage between self- and other-evaluations. *J. Child Psychol. Psychiatry* 52, 774–781. doi: 10.1111/j.1469-7610.2010.02325.x

Rochman, D., and Amir, O. (2013). Examining in-session expressions of emotions with speech/vocal acoustic measures: an introductory guide. *Psychother. Res. J. Soc. Psychother. Res*. 23, 381–393. doi: 10.1080/10503307.2013.784421

Ruscio, A. M. (2010). The latent structure of social anxiety disorder: consequences of shifting to a dimensional diagnosis. *J. Abnorm. Psychol.* 119, 662–671. doi: 10.1037/a0019341

Ruscio, A. M., Brown, T. A., Chiu, W. T., Sareen, J., Stein, M. B., and Kessler, R. C. (2008). Social fears and social phobia in the USA: results from the National Comorbidity Survey Replication. *Psychol. Med*. 38, 15–28. doi: 10.1017/S0033291707001699

Scherer, K. R. (1986). Vocal affect expression: a review and a model for future research. *Psychol. Bull*. 99, 143–165. doi :10.1037/0033-2909.99.2.143

Scherer, K. R., Johnstone, T., and Klasmeyer, G. (2003). *Vocal Expression of Emotion.* New York, NY: Oxford University Press. 433–456.

Sherbourne, C. D., Sullivan, G., Craske, M. G., Roy-Byrne, P., Golinelli, D., Rose, R. D., et al. (2010). Functioning and disability levels in primary care outpatients with one or more anxiety disorders. *Psychol. Med*. 40, 2059–2068. doi: 10.1017/S0033291710000176

Stroud, L. R., Tanofsky-Kraff, M., Wilfley, D. E., and Salovey, P. (2000). The Yale Interpersonal Stressor (YIPS): affective, physiological, and behavioral responses to a novel interpersonal rejection paradigm. *Ann. Behav. Med*. 22, 204–213. doi: 10.1007/BF02895115

Tai, K., Zheng, X., and Narayanan, J. (2011). Touching a teddy bear mitigates negative effects of social exclusion to increase prosocial behavior. *Soc. Psychol. Pers. Sci*. 2, 618–626. doi: 10.1177/1948550611404707

Tusing, K., and Dillard, J. (2000). The sounds of dominance. Vocal precursors of perceived dominance during interpersonal influence. *Hum. Commun. Res*. 26, 148–171. doi: 10.1111/j.1468-2958.2000.tb00754.x

Twenge, J. M., Baumeister, R. F., DeWall, C. N., Ciarocco, N. J., and Bartels, J. M. (2007). Social exclusion decreases prosocial behavior. *J. Pers. Soc. Psychol*. 92, 56–66. doi: 10.1037/0022-3514.92.1.56

Twenge, J. M., Baumeister, R. F., Tice, D. M., and Stucke, T. S. (2001). If you can't join them, beat them: effects of social exclusion on aggressive behavior. *J. Pers. Soc. Psychol*. 81, 1058–1069. doi: 10.1037/0022-3514.81.6.1058

Van Beest, I., and Williams, K. D. (2006). When inclusion costs and ostracism pays, ostracism still hurts. *J. Pers. Soc. Psychol*. 91, 918–928. doi: 10.1037/0022-3514.91.5.918

Wallace, S. T., and Alden, L. E. (1997). Social phobia and positive social events: the price of success. *J. Abnorm. Psychol*. 106, 416–424. doi: 10.1037/0021-843X.106.3.416

Weeks, J. W. (2010). The disqualification of positive social outcomes scale: a novel assessment of a long-recognized cognitive tendency in social anxiety disorder. *J. Anxiety Disord*. 24, 856–865. doi: 10.1016/j.janxdis.2010.06.008

Weeks, J. W., Heimberg, R. G., and Heuer, R. (2011). Exploring the role of behavioral submissiveness in social anxiety. *J. Soc. Clin. Psychol*. 30, 217–249. doi: 10.1521/jscp.2011.30.3.217

Weeks, J. W., and Howell, A. N. (2012). The bivalent fear of evaluation model of social anxiety: further integrating findings on fears of positive and negative evaluation. *Cogn. Behav. Ther.* 41, 83–95. doi: 10.1080/16506073.2012.661452

Weeks, J. W., Lee, C.-Y., Reilly, A. R., Howell, A. N., France, C., Kowalsky, J. M., et al. (2012). "The Sound of Fear": assessing vocal fundamental frequency as a physiological indicator of social anxiety disorder. *J. Anxiety Disord*. 26, 811–822. doi: 10.1016/j.janxdis.2012.07.005

Wesselmann, E. D., Nairne, J. S., and Williams, K. D. (2012a). An evolutionary social psychological approach to studying the effects of ostracism. *J. Soc. Evol. Cult. Psychol*. 6, 309–328. doi: 10.1037/h0099249

Wesselmann, E. D., Wirth, J. H., Mroczek, D. K., and Williams, K. D. (2012b). Dial a feeling: detecting moderation of affect decline during ostracism. *Pers. Individ. Dif*. 53, 580–586. doi: 10.1016/j.paid.2012.04.039

Wiggins, J. S. (1979). A psychological taxonomy of trait-descriptive terms: the interpersonal domain. *J. Pers. Soc. Psychol.* 37, 395–412. doi: 10.1037/0022-3514.37.3.395

Williams, K. D. (1997). *Social Ostracism*. New York, NY: Plenum Press.

Williams, K. D. (2001). *Ostracism: The Power of Silence.* New York, NY: Guilford Press.

Williams, K. D. (2009). *Ostracism: A Temporal Need-Threat Model.* San Diego, CA: Elsevier Academic Press. 275–314. doi: 10.1016/S0065-2601(08)00406-1

Williams, K. D., Cheung, C. K. T., and Choi, W. (2000). Cyberostracism: Effects of being ignored over the Internet. *J. Pers. Soc. Psychol.* 79, 748–762. doi: 10.1037/0022-3514.79.5.748

Williams, K. D., and Zadro, L. (2005). *Ostracism: The Indiscriminate Early Detection System* New York, NY: Psychology Press, 19–34.

Xu, J., and Roberts, R. E. (2010). The power of positive emotions: it's a matter of life or death—Subjective well-being and longevity over 28 years in a general population. *Health Psychol.* 29, 9–19. doi: 10.1037/a0016767

Zadro, L., Boland, C., and Richardson, R. (2006). How long does it last? The persistence of the effects of ostracism in the socially anxious. *J. Exp. Soc. Psychol.* 42, 692–697. doi: 10.1016/j.jesp.2005.10.007

Zadro, L., Williams, K. D., and Richardson, R. (2004). How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *J. Exp. Soc. Psychol.* 40, 560–567. doi: 10.1016/j.jesp.2003.11.006

Zuckerman, M., Larrance, D. T., Spiegel, N. H., and Klorman, R. (1981). Controlling nonverbal displays: facial expressions and tone of voice. *J. Exp. Soc. Psychol.* 17, 506–524. doi: 10.1016/0022-1031(81)90037-8

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Gaze perception in social anxiety and social anxiety disorder

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Clinical observations suggest abnormal gaze perception to be an important indicator of social anxiety disorder (SAD). Experimental research has yet paid relatively little attention to the study of gaze perception in SAD. In this article we first discuss gaze perception in healthy human beings before reviewing self-referential and threat-related biases of gaze perception in clinical and non-clinical socially anxious samples. Relative to controls, socially anxious individuals exhibit an enhanced self-directed perception of gaze directions and demonstrate a pronounced fear of direct eye contact, though findings are less consistent regarding the avoidance of mutual gaze in SAD. Prospects for future research and clinical implications are discussed.

Keywords: avoidance, cone of gaze, emotion, eye-tracking, eye gaze, mutual gaze, social anxiety, social anxiety disorder

INTRODUCTION

Social anxiety disorder (SAD) is one of the most common mental disorders with a lifetime prevalence of up to 12% in Western countries (Fehm et al., 2005; Kessler et al., 2005). Hallmark characteristics are intense fear and avoidance of being evaluated or criticized resulting in extreme discomfort and self-consciousness in everyday social situations (American Psychological Association, 2000). Theoretical models highlight the importance of cognitive biases in the processing of ambiguous or negative cues during social interactions for the etiology and/or maintenance of social anxiety (Rapee and Heimberg, 1997; Clark and Mcmanus, 2002). More specifically, studies show that socially anxious individuals have attentional biases in the processing of negative, rejection-related cues (Bar-Haim et al., 2007) and interpret ambiguous social situations as more threatening and negative than healthy controls (e.g., Stopa and Clark, 2000; Beard and Amir, 2009).

Relatively little attention, however, has been paid to biases in gaze perception. This is particularly surprising since individuals with SAD experience intense feelings of being looked at by other individuals and show a marked avoidance and fear of eye contact during social interactions (Schneier et al., 2011b). Biases in the self-referential perception of gaze directions, for instance, might more easily elicit feelings of mutual gaze and being the center of attention, which then will activate fears of being scrutinized by others. Here, we review studies with clinical and non-clinical socially anxious samples on self-referential and threat-related biases in the perception of mutual gaze.

First, mutual gaze perception in healthy human beings will be discussed. Next, biases in the perception of other individuals' gaze in social anxiety will be reviewed with a focus on: (a) whether mutual gaze is more readily perceived; and (b) whether mutual gaze is avoided and perceived as threatening.

GAZE PERCEPTION IN HEALTHY HUMAN BEINGS

Most mammals generally interpret direct gaze as threatening or as a sign of dominance. Humans in contrast often associate mutual gaze with positive interest, such as love and attraction. A preference for direct gaze seems to be present at a very early age: Farroni et al. (2002) found that infants as young as 2 days old prefer to look at faces that gazed directly at them compared to faces with averted gaze. Yet, humans sometimes find eye contact uncomfortable, for example if a stranger keeps staring at them.

Different sources of information are taken into account when processing gaze direction. The most obvious cue lies in the eye itself. Kobayashi and Kohshima (1997, 2001) compared the eyes of a large number of primates and found that the morphology of the human eye is rather unique. Of all compared species human eyes have the highest width to height ratio and the highest index of exposed sclera size. The amount of visible sclera provides information about the orientation of the eyeball (Gibson and Pick, 1963; Cline, 1967; Anstis et al., 1969; Langton et al., 2000; Ando, 2002). Ando (2002) provided direct evidence that the iris/sclera ratio is an important cue for eye gaze perception. By darkening one side of the sclera of eyes directed straight ahead, he found a substantial shift of the perceived gaze direction towards the darkened side.

Another factor influencing gaze perception is the head direction of the looker. Langton (2000) (see also Wollaston, 1824) found that the orientation of another person's head strongly influenced the perceived direction of the person's gaze. Body posture is yet another cue that can provide information about where someone is attending (Perrett et al., 1992).

Studies that focus on the ability to distinguish between direct and averted eye gaze are relatively numerous. All these studies generally report that human observers are highly accurate at determining mutual eye gaze. In their classic study, Gibson and Pick (1963) asked observers to indicate whether a "looker" who was sitting opposite was making eye contact or looking at a peripheral target. The authors found that an angular deviation of the eye by only 2.8° was correctly detected as not making eye contact. Cline (1967) replicated and extended these findings and reported that an angular deviation of as little as 0.75° was readily detected by an observer. Such high accuracy rates in detecting mutual gaze are not undisputed, since a number of studies found relatively poor discrimination of gaze direction, especially when the distance between looker and observer was large (e.g., Vine, 1971). With decreasing security (i.e., when visual information was reduced through distance or noise) observers tended to assume mutual gaze. There thus seems to be a considerable range wherein a person feels being looked at. Gaze direction might hence be better described as a cone rather than a ray (as assumed by e.g., Gibson and Pick, 1963; Cline, 1967). Consequently, Gamer and Hecht (2007) introduced the cone of direct gaze (CoDG) as a concept to measure mutual gaze perception. The authors found an average width of the CoDG of between 4° and 9° of visual angle, depending on the distance between looker and observer.

Facial emotional expression is another cue taken into account when judging gaze directions. Lobmaier et al. (2008) presented participants with three-dimensional models that were either facing the observer, or were rotated 2°, 4°, 6°, 8°, and 10° to the left and right. In this study eye gaze and head direction were aligned with each other (i.e., the whole head was rotated keeping the eyes relative to the head direction constant). Participants were asked to judge whether the face was looking at them or not. The results revealed a remarkable positivity bias: happy faces were more likely perceived as looking at the observer than angry, fearful, or neutral faces. The authors interpreted this finding in favor of self-esteem preservation: perceiving other's happiness as directed at oneself is socially rewarding (see also Lobmaier and Perrett, 2011). This interpretation is compatible with the assumption that human beings have a prior expectation that other people's gaze is directed towards them (Mareschal et al., 2013).

Ewbank et al. (2009) employed the CoDG metaphor to further test the influence of emotional expression on perception of direct gaze. Using the method of constant stimuli (see also Mareschal et al., 2013) angry, fearful and neutral faces were presented in which the direction of eye gaze was manipulated. They found that the CoDG was significantly wider for angry faces compared to neutral and fearful faces.

The studies reviewed above reveal that gaze perception plays an important role in social interactions and is modulated by several factors, such as head direction, interpersonal distance, or emotional facial expressions (see also reviews by Graham and LaBar, 2012; Carlin and Calder, 2013; for behavioral and neuroscientific findings of gaze processing and gaze-emotion interactions). Given that social interactions are affected in SAD, it is conceivable that social anxiety might be associated with impeded gaze perception. In the following sections we discuss gaze perception in the context of SAD.

GAZE PERCEPTION IN SOCIAL ANXIETY AND SOCIAL ANXIETY DISORDER

SELF-DIRECTED PERCEPTION OF GAZE

In recent years, several studies have investigated the perception of self-directed gaze in order to quantify the perception of mutual gaze in social anxiety. Initial work used the previously described "cone of gaze" paradigm to investigate the self-directed perception of gaze cues in SAD (Gamer et al., 2011). In half of the trials an additional task-irrelevant looker was presented. The results provided support that patients with SAD exhibit an enlarged self-directed perception of gaze directions, but only in the presence of a second virtual looker. The magnitude of this effect was positively correlated with the severity of social anxiety symptoms.

Subsequent work investigated dimensional relations between social anxiety and the perception of gaze directions in a non-clinical sample, while also addressing the specific role of facial emotional expressions (Schulze et al., 2013). Severity of social anxiety was positively correlated with the self-directed perception of other individuals' gaze, especially when the "lookers" exhibited a neutral or negative (i.e., angry, fearful) facial expression. In addition, response latencies negatively interacted with symptoms of social anxiety, presumably reflecting an increased avoidance of direct gaze. Similar findings were reported by Jun et al. (2013) who assessed self-directed gaze perception using male facial stimuli in students with high and low social anxiety. An increased cone of gaze was found only in male students with marked social anxiety, possibly because male students experienced greater discomfort when being looked at than females (see also Jun et al., 2013, for a discussion of possible interactions between the sex of "lookers" and "observers" in mutual gaze perception).

Notably, enhanced self-referential perception of gaze directions was also demonstrated in more ecologically valid experimental setups with alive target stimuli. Harbort et al. (2013) studied the effects of real persons and virtual heads on gaze perception. The findings underpinned that the CoDG was generally increased in SAD, but that effect sizes were larger in the *Real-Person-Condition* than in the *Virtual-Head-Condition*. The widening of the gaze cone in the *Real-Person-Condition* was suggested to be a consequence of higher arousal in SAD patients when confronted with a real person. In line with the proposed role of arousal, stress-induced increases in cortisol levels were previously shown to increase feelings of being looked at (Rimmele and Lobmaier, 2012). A face-to-face situation was also used by Honma (2013) who found the range of gaze directions perceived as self-directed to be much larger than the actual amount of eye contact and perception of mutual gaze was accompanied by greater pupil dilations (see also Honma et al., 2012). In this study, severity of social anxiety was positively correlated with perceived eye contact and pupil dilation.

Harbort et al. (2013) assessed the effects of Cognitive Behavioral Therapy (CBT) on gaze perception. Patients with SAD were tested prior to standardized CBT and again after approximately 24 therapy sessions had been completed. Prior to psychotherapeutic treatment, patients with SAD were characterized by increased perceptions of gaze as being self-directed. Intriguingly, after CBT patients with SAD did not differ from healthy controls, suggesting that interventions aiming at reducing SAD symptoms lead to a normalization of the gaze cone. These findings still need to be considered preliminary since the interaction of group and assessment time failed to reach significance; several alternative explanations might thus account for the observed pattern.

In sum, available studies in SAD demonstrated an abnormal perception of mutual gaze, providing a quantification of the intense feelings of being looked at. Findings unanimously demonstrated an enhanced self-directed perception of gaze, particularly for negative and neutral facial expressions. Further studies are needed to investigate whether the cone of gaze changes due to psychotherapeutic interventions.

THREAT PERCEPTION AND AVOIDANCE OF MUTUAL GAZE

Clinical observations suggest fear and avoidance of *direct* eye contact to be prominent characteristics of SAD. Yet, empirical evidence on threat-related perception and avoidance of direct gaze compared with averted gaze is still scarce.[1]

Initial studies provided some support that mutual gaze is feared and avoided in social interactions (e.g., Daly, 1978; Baker and Edelmann, 2002). These findings are however limited because subjective observations were used as dependent measures. Objective evidence for an avoidance of salient facial features was first provided by studies using eye-tracking to investigate visual responses to static images with direct gaze. Comparing visual scanpaths of emotional facial expressions in patients with SAD and healthy controls yielded an active avoidance of salient facial features such as the eye region in SAD. This was particularly reflected in reduced number and duration of fixations of the eye region while a "hyperscanning" strategy was exhibited for remaining facial features (Horley et al., 2003, 2004). This distinct visual scanning behavior was most prominent for expressions of threat, whereas group differences were least pronounced in response to neutral or happy facial expressions (Horley et al., 2003, 2004). Moukheiber et al. (2010) later replicated these results, finding less fixations and shorter dwell times on the eye region in SAD compared to healthy individuals. Again, group differences were most notable for expressions of social threat (i.e., anger and disgust). A reduced number and duration of fixations upon the eye region were also reported when SAD patients received social feedback (Weeks et al., 2013).

While these studies demonstrate an avoidance of the eye region, questions remained unanswered to what extent others' gaze directions differentially affect avoidance behavior in SAD. This question was recently addressed by means of the Approach-Avoidance Task. In social anxiety, behavioral avoidance of angry faces was present only when coupled with direct gaze (Roelofs et al., 2010). Notably, administration of oxytocin facilitated approach behavior towards angry faces with direct gaze in socially anxious individuals (Radke et al., 2013). In a related line of research, fixation behavior was investigated in response to animated video clips of faces with direct or averted gaze (Wieser et al., 2009a). In high socially anxious participants longer fixations on the eye region were observed, although effects were only marginally significant. Additionally, heightened physiological arousal in socially anxious individuals was found for direct compared to averted gaze suggesting that mutual gaze is perceived as threatening. In line with this interpretation, increased startle reactivity was observed the very moment a virtual audience directed their eye gaze and attention towards individuals with SAD who had to deliver a speech (Cornwell et al., 2011). A virtual-reality environment was also used by Wieser et al. (2010) to scrutinize the interplay between gaze directions, interpersonal distance, and sex of the interaction partner on avoidance behavior. Socially anxious individuals were found to avoid eye contact and to show increased backward head movements in response to male avatars with direct gaze.

Further evidence for the threatening quality of direct gaze was obtained by functional neuroimaging studies in SAD (see Etkin and Wager, 2007 for a meta-analysis of neuroimaging and emotion processing in SAD). In a preliminary study comparing neural responses to direct and averted gaze, patients with SAD were found to exhibit greater activation in parts of the fear circuitry including the amygdala, insula, and anterior cingulate cortex (Schneier et al., 2009). Additional eye tracking results indicated that SAD patients show a greater avoidance of the eye region in stimuli with direct compared to averted gaze than healthy controls. In a subsequent study, neural responses to direct and averted gaze were assessed before and after intervention with paroxetine in patients with generalized SAD (gSAD; Schneier et al., 2011a). At baseline, gSAD patients showed greater activation than healthy controls in brain regions related to self-referential processing and emotion regulation such as cortical midline structures of the ventromedial prefrontal cortex and the posterior cingulate cortex, when looking at direct versus averted gaze. However, fixation of the eye region did not differ significantly between gSAD patients and healthy controls. Pharmacological treatment resulted in a normalization of brain activation in response to direct gaze.

In contrast to the studies reviewed above, recent electrophysiological evidence suggested a specific processing bias for averted gaze in social anxiety as implied by enhanced late positive potentials and (marginally significant) higher amplitudes of the P100 in response to averted gaze (Schmitz et al., 2012). These authors proposed that direct gaze might only be perceived as threatening when coupled with negative facial expressions, whereas neutral expressions with averted gaze might rather signal disinterest.

Taken together, there is ample evidence that mutual gaze is perceived as threatening by socially anxious individuals. However, findings are less consistent regarding the avoidance of mutual gaze in SAD. While several studies demonstrated an avoidance of the eye region when coupled with direct gaze, some studies failed to observe group differences and one study even reported prolonged fixation of the eye region. Future research suggestions will be discussed in the final section.

[1]Note that the present review is focused specifically on *gaze perception*. For studies using eye-tracking in SAD to investigate attention mechanisms in general, see Armstrong and Olatunji (2012).

SUMMARY AND FUTURE RESEARCH

Clinical observations suggest abnormalities in gaze perception to be important for SAD. In accordance with such claims, findings from analog samples and clinical populations demonstrated a greater cone of gaze and a pronounced fear of direct eye contact in social anxiety. In addition, recent findings suggest that individuals with SAD avoid mutual gaze, but these results are less consistent.

In socially anxious individuals, a biased self-referential perception of gaze directions may underlie the fear of being the center of attention and cause uneasiness and discomfort. Specifically, biased perceptions of mutual gaze may lead socially anxious individuals to appraise a situation as social, which results in a heightened processing of the self as a social object, ultimately resulting in a negative cascade of somatic, cognitive, and behavioral consequences (Clark and Mcmanus, 2002). The avoidance of eye contact in social anxiety may be understood as an attempt to avoid signs of social threat and to regulate excessive fears of being evaluated. This avoidance behavior may contribute to the maintenance of SAD by negatively reinforcing expectations and fears of social encounters. Alternatively, taking into account findings of gaze aversion in social anxiety, it is also conceivable that SAD patients fail to extract relevant cues from the eye region. This factor may lead to abnormal perceptions of being looked at. A promising direction for future studies may therefore be to combine eye-tracking methods with paradigms of mutual gaze perception to further disentangle causes and consequences of abnormal gaze perception/behavior in social anxiety.

Measuring scan paths by means of eye-tracking is a highly ecologically valid method to assess overt gazing behavior. Hence, eye-tracking methods seem highly suitable to study avoidance of mutual gaze in individuals with social anxiety. In addition, such methods also allow studying approach-avoidance behavior in response to more ecologically valid stimuli, such as films or crowds of individuals (Lange et al., 2011). Ultimately, gaze measures may present objective benchmarks for the evaluation of psychotherapeutic treatment approaches for SAD. More specifically, scan paths may potentially be used as objective measures for avoidance behavior in social anxiety. Although the avoidance of mutual gaze is considered a behavioral marker of SAD (cf. Weeks et al., 2013), current findings are less consistent in this regard. A possible explanation for these inconsistencies may be that in most studies only *time-averaged* fixation behavior in response to direct gaze was analyzed. However, behavioral studies mainly suggest a hypervigilant-avoidant *time-course* of attention in social anxiety. In comparison to non-anxious individuals, threatening social information is detected earlier by socially anxious individuals (hypervigilance) and is followed by attentional avoidance of such stimuli (e.g., Wieser et al., 2009b). More fine-grained analyses and paradigms might thus help to disentangle differential effects of early and late processes on fixation behavior in SAD (see also Bar-Haim et al., 2007; Armstrong and Olatunji, 2012).

Further research is needed to assess the diagnostic value of abnormalities in gaze perception as possible behavioral indicators of SAD. To date, statements regarding the diagnostic potential of such measures are substantially limited since none of the studies included a clinical comparison group, comprising for instance individuals with symptoms of autism, or schizophrenia who also exhibit abnormal gaze perception (Kliemann et al., 2010; Clark et al., 2013). It remains therefore unclear whether avoidance and fear of gaze are specific for socially anxious individuals or whether they are general signs of psychopathology and interpersonal dysfunction. Furthermore, the specific functions of gaze avoidance and its effects on states of social anxiety remain to be clarified. Langer and Rodebaugh (2013) recently demonstrated avoidance of eye-to-eye contact to be an ineffective strategy for the regulation of anxiety in social phobic individuals.

In sum, recent findings highlighted abnormal gaze perceptions in social anxiety. In particular, socially anxious individuals were characterized by a greater self-referential perception of gaze direction along with a pronounced fear of direct eye contact.

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REFERENCES

American Psychological Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision (DSM-IV-TR)*. Washington: APA.

Ando, S. (2002). Luminance-induced shift in the apparent direction of gaze. *Perception* 31, 657–674. doi: 10.1068/p3332

Anstis, S. M., Mayhew, J. W., and Morley, T. (1969). The perception of where a face or television "portrait" is looking. *Am. J. Psychol.* 82, 474–489. doi: 10.2307/1420441

Armstrong, T., and Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: a meta-analytic review and synthesis. *Clin. Psychol. Rev.* 32, 704–723. doi: 10.1016/j.cpr.2012.09.004

Baker, S. R., and Edelmann, R. J. (2002). Is social phobia related to lack of social skills? Duration of skill-related behaviours and ratings of behavioural adequacy. *Br. J. Clin. Psychol.* 41, 243–257. doi: 10.1348/014466502760379118

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., and Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol. Bull.* 133, 1–24. doi: 10.1037/0033-2909.133.1.1

Beard, C., and Amir, N. (2009). Interpretation in social anxiety: when meaning precedes ambiguity. *Cognit. Ther. Res.* 33, 406–415. doi: 10.1007/s10608-009-9235-0

Carlin, J. D., and Calder, A. J. (2013). The neural basis of eye gaze processing. *Curr. Opin. Neurobiol.* 23, 450–455. doi: 10.1016/j.conb.2012.11.014

Clark, C. M., Gosselin, F., and Goghari, V. M. (2013). Aberrant patterns of visual facial information usage in schizophrenia. *J. Abnorm. Psychol.* 122, 513–519. doi: 10.1037/a0031944

Clark, D. M., and Mcmanus, F. (2002). Information processing in social phobia. *Biol. Psychiatry* 51, 92–100. doi: 10.1016/s0006-3223(01)01296-3

Cline, M. G. (1967). The perception of where a person is looking. *Am. J. Psychol.* 80, 41–50. doi: 10.2307/1420539

Cornwell, B. R., Heller, R., Biggs, A., Pine, D. S., and Grillon, C. (2011). Becoming the center of attention in social anxiety disorder: startle reactivity to a virtual audience during speech anticipation. *J. Clin. Psychiatry* 72, 942–948. doi: 10.4088/jcp.09m05731blu

Daly, S. (1978). Behavioral correlates of social anxiety. *Br. J. Soc. Clin. Psychol.* 17, 117–120. doi: 10.1111/j.2044-8260.1978.tb00252.x

Etkin, A., and Wager, T. D. (2007). Functional neuroimaging of anxiety: a meta-analysis of emotional processing in PTSD, social anxiety disorder and specific phobia. *Am. J. Psychiatry* 164, 1476–1488. doi: 10.1176/appi.ajp.2007.07030504

Ewbank, M. P., Jennings, C., and Calder, A. J. (2009). Why are you angry with me? Facial expressions of threat influence perception of gaze direction. *J. Vis.* 9:16. doi: 10.1167/9.12.16

Farroni, T., Csibra, G., Simion, F., and Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proc. Natl. Acad. Sci. U S A* 99, 9602–9605. doi: 10.1073/pnas.152159999

Fehm, L., Pelissolo, A., Furmark, T., and Wittchen, H. U. (2005). Size and burden of social phobia in Europe. *Eur. Neuropsychopharmacol.* 15, 453–462. doi: 10.1016/j.euroneuro.2005.04.002

Gamer, M., and Hecht, H. (2007). Are you looking at me? Measuring the cone of gaze. *J. Exp. Psychol. Hum. Percept. Perform.* 33, 705–715. doi: 10.1037/0096-1523.33.3.705

Gamer, M., Hecht, H., Seipp, N., and Hiller, W. (2011). Who is looking at me? The cone of gaze widens in social phobia. *Cogn. Emot.* 25, 756–764. doi: 10.1080/02699931.2010.503117

Gibson, J. J., and Pick, A. D. (1963). Perception of another person's looking behavior. *Am. J. Psychol.* 76, 386–394. doi: 10.2307/1419779

Graham, R., and LaBar, K. S. (2012). Neurocognitive mechanisms of gaze-expression interactions in face processing and social attention. *Neuropsychologia* 50, 553–566. doi: 10.1016/j.neuropsychologia.2012.01.019

Harbort, J., Witthoft, M., Spiegel, J., Nick, K., and Hecht, H. (2013). The widening of the gaze cone in patients with social anxiety disorder and its normalization after CBT. *Behav. Res. Ther.* 51, 359–367. doi: 10.1016/j.brat.2013.03.009

Honma, M. (2013). Hyper-volume of eye-contact perception and social anxiety traits. *Conscious. Cogn.* 22, 167–173. doi: 10.1016/j.concog.2012.12.002

Honma, M., Tanaka, Y., Osada, Y., and Kuriyama, K. (2012). Perceptual and not physical eye contact elicits pupillary dilation. *Biol. Psychol.* 89, 112–116. doi: 10.1016/j.biopsycho.2011.09.015

Horley, K., Williams, L. M., Gonsalvez, C., and Gordon, E. (2003). Social phobics do not see eye to eye: a visual scanpath study of emotional expression processing. *J. Anxiety Disord.* 17, 33–44. doi: 10.1016/s0887-6185(02)00180-9

Horley, K., Williams, L. M., Gonsalvez, C., and Gordon, E. (2004). Face to face: visual scanpath evidence for abnormal processing of facial expressions in social phobia. *Psychiatry Res.* 127, 43–53. doi: 10.1016/j.psychres.2004.02.016

Jun, Y. Y., Mareschal, I., Clifford, C. W., and Dadds, M. R. (2013). Cone of direct gaze as a marker of social anxiety in males. *Psychiatry Res.* 210, 193–198. doi: 10.1016/j.psychres.2013.05.020

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., and Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV disorders in the national comorbidity survey replication. *Arch. Gen. Psychiatry* 62, 593–602. doi: 10.1001/archpsyc.62.6.593

Kliemann, D., Dziobek, I., Hatri, A., Steimke, R., and Heekeren, H. R. (2010). Atypical reflexive gaze patterns on emotional faces in autism spectrum disorders. *J. Neurosci.* 30, 12281–12287. doi: 10.1523/jneurosci.0688-10.2010

Kobayashi, H., and Kohshima, S. (1997). Unique morphology of the human eye. *Nature* 387, 767–768. doi: 10.1038/42842

Kobayashi, H., and Kohshima, S. (2001). Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye. *J. Hum. Evol.* 40, 419–435. doi: 10.1006/jhev.2001.0468

Lange, W. G., Heuer, K., Langner, O., Keijsers, G. P., Becker, E. S., and Rinck, M. (2011). Face value: eye movements and the evaluation of facial crowds in social anxiety. *J. Behav. Ther. Exp. Psychiatry* 42, 355–363. doi: 10.1016/j.jbtep.2011.02.007

Langer, J. K., and Rodebaugh, T. L. (2013). Social anxiety and gaze avoidance: averting gaze but not anxiety. *Cognit. Ther. Res.* 37, 1110–1120. doi: 10.1007/s10608-013-9546-z

Langton, S. R. (2000). The mutual influence of gaze and head orientation in the analysis of social attention direction. *Q. J. Exp. Psychol. A* 53, 825–845. doi: 10.1080/027249800410562

Langton, S. R., Watt, R. J., and Bruce, I. I. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends Cogn. Sci.* 4, 50–59. doi: 10.1016/s1364-6613(99)01436-9

Lobmaier, J. S., and Perrett, D. I. (2011). The world smiles at me: self-referential positivity bias when interpreting direction of attention. *Cogn. Emot.* 25, 334–341. doi: 10.1080/02699931003794557

Lobmaier, J. S., Tiddeman, B., and Perrett, D. I. (2008). Emotional expression modulates perceived gaze direction. *Emotion* 8, 573–577. doi: 10.1037/1528-3542.8.4.573

Mareschal, I., Calder, A. J., and Clifford, C. W. (2013). Humans have an expectation that gaze is directed toward them. *Curr. Biol.* 23, 717–721. doi: 10.1016/j.cub.2013.03.030

Moukheiber, A., Rautureau, G., Perez-Diaz, F., Soussignan, R., Dubal, S., Jouvent, R., et al. (2010). Gaze avoidance in social phobia: objective measure and correlates. *Behav. Res. Ther.* 48, 147–151. doi: 10.1016/j.brat.2009.09.012

Perrett, D. I., Hietanen, J. K., Oram, M. W., and Benson, P. J. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 335, 23–30. doi: 10.1098/rstb.1992.0003

Radke, S., Roelofs, K., and de Bruijn, E. R. (2013). Acting on anger: social anxiety modulates approach-avoidance tendencies after oxytocin administration. *Psychol. Sci.* 24, 1573–1578. doi: 10.1177/0956797612472682

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/s0005-7967(97)00022-3

Rimmele, U., and Lobmaier, J. S. (2012). Stress increases the feeling of being looked at. *Psychoneuroendocrinology* 37, 292–298. doi: 10.1016/j.psyneuen.2011.06.013

Roelofs, K., Putman, P., Schouten, S., Lange, W. G., Volman, I., and Rinck, M. (2010). Gaze direction differentially affects avoidance tendencies to happy and angry faces in socially anxious individuals. *Behav. Res. Ther.* 48, 290–294. doi: 10.1016/j.brat.2009.11.008

Schmitz, J., Scheel, C. N., Rigon, A., Gross, J. J., and Blechert, J. (2012). You don't like me, do you? Enhanced ERP responses to averted eye gaze in social anxiety. *Biol. Psychol.* 91, 263–269. doi: 10.1016/j.biopsycho.2012.07.004

Schneier, F. R., Kent, J. M., Star, A., and Hirsch, J. (2009). Neural circuitry of submissive behavior in social anxiety disorder: a preliminary study of response to direct eye gaze. *Psychiatry Res.* 173, 248–250. doi: 10.1016/j.pscychresns.2008.06.004

Schneier, F. R., Pomplun, M., Sy, M., and Hirsch, J. (2011a). Neural response to eye contact and paroxetine treatment in generalized social anxiety disorder. *Psychiatry Res.* 194, 271–278. doi: 10.1016/j.pscychresns.2011.08.006

Schneier, F. R., Rodebaugh, T. L., Blanco, C., Lewin, H., and Liebowitz, M. R. (2011b). Fear and avoidance of eye contact in social anxiety disorder. *Compr. Psychiatry* 52, 81–87. doi: 10.1016/j.comppsych.2010.04.006

Schulze, L., Lobmaier, J. S., Arnold, M., and Renneberg, B. (2013). All eyes on me?! Social anxiety and self-directed perception of eye gaze. *Cogn. Emot.* 27, 1305–1313. doi: 10.1080/02699931.2013.773881

Stopa, L., and Clark, D. M. (2000). Social phobia and interpretation of social events. *Behav. Res. Ther.* 38, 273–283. doi: 10.1016/s0005-7967(99)00043-1

Vine, I. (1971). Judgement of direction of gaze: an interpretation of discrepant results. *Br. J. Soc. Clin. Psychol.* 10, 320–331. doi: 10.1111/j.2044-8260.1971.tb00756.x

Weeks, J. W., Howell, A. N., and Goldin, P. R. (2013). Gaze avoidance in social anxiety disorder. *Depress. Anxiety* 30, 749–756. doi: 10.1002/da.22146

Wieser, M. J., Pauli, P., Alpers, G. W., and Muhlberger, A. (2009a). Is eye to eye contact really threatening and avoided in social anxiety? An eye-tracking and psychophysiology study. *J. Anxiety Disord.* 23, 93–103. doi: 10.1016/j.janxdis.2008.04.004

Wieser, M. J., Pauli, P., Grosseibl, M., Molzow, I., and Mühlberger, A. (2010). Virtual social interactions in social anxiety - the impact of sex, gaze and interpersonal distance. *Cyberpsychol. Behav. Soc. Netw.* 13, 547–554. doi: 10.1089/cyber.2009.0432

Wieser, M. J., Pauli, P., Wyers, P., Alpers, G. W., and Mühlberger, A. (2009b). Fear of negative evaluation and the hypervigilance-avoidance hypothesis: an eye-tracking study. *J. Neural Transm.* 116, 717–723. doi: 10.1007/s00702-008-0101-0

Wollaston, W. H. (1824). On the apparent direction of eyes in a portrait. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 114, 247–256. doi: 10.1098/rstl.1824.0016

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Subliminal attention bias modification training in socially anxious individuals

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Anxious individuals demonstrate threat-related attention biases both when threat stimuli are presented within conscious awareness and when presented below awareness threshold. Nevertheless, attention bias modification (ABM) research has rarely utilized sub-awareness protocols in an attempt to modify attention patterns and reduce anxiety. Exploring the potential of subliminal ABM is of interest, as it may target attention processes related to anxiety that are distinct from those engaged by supraliminal ABM. Here we examined the effect of a subliminal ABM training protocol on levels of social anxiety and stress vulnerability. Fifty-one socially anxious students were randomly assigned to either ABM or placebo condition, and completed a pre-training assessment, four training sessions, a social stressor task, and a post-training assessment. Results indicate that the subliminal ABM used here did not induce detectable changes in threat-related attention from pre- to post-training as measured by two independent attention tasks. Furthermore, the ABM and placebo groups did not differ on either self-reported social anxiety post-training or state anxiety following stress induction. *Post-hoc* auxiliary analyses suggest that ABM may be associated with smaller elevations in state anxiety during the stressor task only for participants who demonstrate attention bias toward threat at baseline. Implications and future research directions are discussed.

Keywords: social anxiety, stress vulnerability, attention bias modification, masking, subliminal

INTRODUCTION

Numerous studies across clinical and sub-clinical populations have found that anxious individuals demonstrate an attentional bias toward threat-related stimuli (Bar-Haim et al., 2007). This bias manifests even when threat stimuli are presented below awareness thresholds (Mathews and MacLeod, 1986; Mogg et al., 1993; van den Hout et al., 1995; Fox, 2002; Mogg and Bradley, 2002). Additional findings further suggest that threat biases causally affect stress vulnerability (MacLeod et al., 2002; Mathews and MacLeod, 2002; Eldar et al., 2008). Based on such observations, attention bias modification (ABM) treatments have started to emerge, exploring the potential of computerized tools to modify attention patterns and consequently reduce stress-vulnerability and anxiety (Koster et al., 2009; Bar-Haim, 2010; Hakamata et al., 2010; Beard, 2011; Hallion and Ruscio, 2011).

Clinical ABM trials indicate that training patients to attend away from threat reduces self-reported as well as clinically evaluated anxiety levels (Amir et al., 2009, 2011; Schmidt et al., 2009; Eldar et al., 2012). In addition, studies with non-clinical high-anxious participants show that ABM training typically reduces stress vulnerability in the face of lab-induced (Amir et al., 2008; Bar-Haim et al., 2011) or real-life (See et al., 2009) stressors. However, although many studies have utilized subliminal stimuli to measure preconscious threat-related attention biases and their associations to anxiety and stress vulnerability (MacLeod and Hagan, 1992; van den Hout et al., 1995; Fox et al., 2010), the vast majority of ABM studies to date have used supraliminal (i.e., consciously perceived) stimuli presentations to modify these biases.

Exploring the potential of subliminal ABM is of interest, as it may target a different layer of attention processes related to anxiety. In line with this idea, brain imaging and psychophysiology studies found distinct responses to readily-identifiable, as opposed to masked, subliminal threat-related stimuli in anxious relative to non-anxious individuals (Ohman and Soares, 1994; Etkin et al., 2004; Li et al., 2007; Tsunoda et al., 2008). These findings suggest that hypersensitivity to threat in anxious individuals may occur prior to conscious awareness. For example, Etkin et al. (2004) demonstrated that supraliminal and subliminal presentations of threat faces modulated neural activation in distinct regions of the amygdala. Specifically, subliminal presentations modulated activity in the basolateral region of the amygdala, and this activation was positively correlated with trait anxiety. Thus, subliminal ABM may provide an opportunity to intervene with anxiety-maintaining mechanisms that act very early in the processing stream.

To our knowledge only one study used subliminal presentations in the context of ABM. MacLeod et al. (2002; study 1) used a dot-probe task to train non-anxious students to attend either to threat or neutral words. A single-session protocol with 576 active training trials was used, in which half of the trials were presented subliminally and half were presented well within conscious awareness. In addition, 96 attention bias measurement trials were intermixed throughout the active training trials. Half of these measurement trials were subliminally presented and the other half were presented within conscious awareness. Following training, lower stress vulnerability was found in the group trained to attend away from threat relative to the group trained to attend toward threat. The results also indicated that attentional changes following training emerged only for consciously presented measurement trials and not for subliminal measurement trials. However, because all trial types (subliminal, supraliminal; training, measurement) were presented in a mixed fashion, conclusive inference on the specific effect of subliminal training was complicated. Moreover, as mentioned, this study included only non-anxious participants. It has been previously demonstrated that non-anxious individuals' attention is less reactive to subliminal threatening stimuli as compared to anxious individuals (Mathews and MacLeod, 1986; Mogg et al., 1993). This could suggest a possible explanation as to why no change in preconscious attention processes was demonstrated following training among these non-anxious subjects. Finally, the study by MacLeod et al. (2002) used word stimuli that might be less optimal than evolutionary-relevant threat, such as faces (Ohman and Mineka, 2001), for early threat-attention modification processes. Thus, it appears that more research is needed to explore the effects of subliminal ABM on anxiety and stress vulnerability among anxious individuals.

The aim of the current study was to examine the efficacy of a subliminal dot-probe ABM protocol on attention bias, anxiety levels, and stress vulnerability in a group of undergraduate students with high levels of self-reported social anxiety. We decided to focus on socially anxious individuals for several reasons: first, for methodological reasons, we wanted to keep our sample as homogenous as possible with respect to the nature of their anxiety. This enabled us to specify the stimuli and the stressful manipulation to the characteristics of this particular anxiety. Second, we selected this specific population because previous findings indicate ABM efficacy with supraliminal presentations in clinically diagnosed Social Anxiety Disorder patients (Amir et al., 2009; Schmidt et al., 2009; Heeren et al., 2011, 2012), as well as in analog samples with moderate to high self-reported social anxiety (Amir et al., 2008; Klumpp and Amir, 2010). The subliminal ABM protocol used in the current study followed the parameters from these previous supraliminal ABM studies, which have demonstrated positive effects of ABM in socially anxious populations (Amir et al., 2008, 2009; Schmidt et al., 2009), but with subliminal presentations. We expected the subliminal ABM protocol to change threat-related attention patterns in accord with the training condition. That is, that participants trained to attend away from threats would show a reduction in threat-related attention bias following ABM. No change in attention pattern was expected in the placebo control condition which was not intended to manipulate attention. We also expected that participants in the ABM condition will display less anxiety and lower stress vulnerability following training relative to participants in the placebo control condition.

METHODS

PARTICIPANTS

Sixty socially anxious undergraduate students were invited to participate in the study based on their high total scores (>30) on the Liebowitz Social Anxiety Scale (LSAS, Liebowitz, 1987) completed in a mass survey at the beginning of the academic year. A cutoff score of 30 was found to provide the best balance between false positive and false negative diagnostic errors in classifying individuals with social anxiety disorder (Mennin et al., 2002; Rytwinski et al., 2009). The LSAS was again administered to these 60 students in the lab during the pre-assessment session of the study to verify high social anxiety levels. Eight students reported lower levels of social anxiety relative to their initial report and no longer met the criterion of LSAS >30. These students were thus excluded from further participation in the study. An additional student decided not to participate. Thus, 51 participants (mean age = 22.70 years, SD = 1.65; 41 females) were randomly assigned to either an ABM group ($n = 24$) or a placebo control group ($n = 27$). The mean LSAS score for the final sample was 55.73 ($SD = 16.90$), placing their mean score more than 3 standard deviations above the mean for individuals with no axis I diagnosis (Fresco et al., 2001). The groups did not differ in age, gender distribution, baseline threat bias scores, and mean LSAS scores, all $ps > 0.15$ (see **Table 1** for baseline means and SDs by group, and **Figure 1** for a CONSORT diagram). The study was approved by the institutional review board. Participants provided signed informed consent.

QUESTIONNAIRES

Social anxiety was assessed with the LSAS (Liebowitz, 1987). This scale consists of 24 items describing social interactions and performance situations. The LSAS possesses strong psychometric properties (Fresco et al., 2001). The Hebrew version of the LSAS was found valid and reliable (Levin et al., 2002). Cronbach's alpha in the current sample was 0.90 and 0.93 for the baseline and post-ABM/Placebo sessions, respectively.

State anxiety was measured with the state sub-scale (STAI-S) of the State-Trait Anxiety Inventory (STAI, Spielberger et al., 1983). The STAI-S consists of 20 items measuring current, situational levels of anxiety. The Hebrew version of the STAI was found valid and reliable (Teichman and Melinic, 1979). Cronbach's alpha in the current sample was 0.89 or higher in each of the STAI-S administrations (baseline, pre and during the stressor task, and at post measurement).

ATTENTIONAL BIAS ASSESSMENT

The dot probe task

The sequence of events on a dot-probe trial is described in **Figure 2**. Each trial began with the presentation of a fixation display (500 ms; white cross 1 × 1 cm), on which the participants were requested to focus their gaze. The fixation display was followed by a presentation of a pair of faces. Face pairs comprised either disgust-neutral or neutral-neutral facial expressions of the same actor. Pictures of eight different actors were used (four female), taken from a standardized set of emotional expressions (Matsumoto and Ekman, 1988). Each face photograph was placed on a gray square background subtending

Table 1 | Means and SDs of baseline, post-training, pre-stressor, and during-stressor measurements by group*.

	Baseline		Post-training	
	ABM	Placebo-Control	ABM	Placebo-Control
Gender (F/M)	20/4	20/6		
Age	22.96 (1.94)	22.42 (1.33)		
LSAS score	54.67 (14.55)	55.96 (18.99)	53.63 (16.88)	54.62 (21.28)
STAI-S score	38.00 (10.80)	38.35 (7.92)	34.59 (9.28)	38.54 (9.50)
DOT-PROBE				
Mean RT—threat	527 (63)	533 (47)	478 (44)	470 (39)
Mean RT—neutral	527 (58)	532 (50)	479 (40)	469 (33)
Threat bias score	0.10 (19)	−0.88 (18)	1.01 (18)	−0.97 (17)
AFFECTIVE SPATIAL CUING				
Mean RT—threat valid	585 (92)	565 (69)	556 (79)	542 (56)
Mean RT—neutral valid	582 (94)	562 (70)	559 (76)	542 (59)
Mean RT—threat invalid	659 (118)	666 (98)	636 (106)	646 (84)
Mean RT—neutral invalid	675 (146)	664 (92)	635 (102)	647 (89)
Threat engagement	−3.06 (23)	−2.35 (22)	3.59 (22)	−0.49 (20)
Threat disengagement	−16.04 (54)	1.52 (40)	0.74 (36)	−0.83 (37)
	Pre-stressor		**During-stressor**	
	ABM	**Placebo-Control**	**ABM**	**Placebo-Control**
STAI-S score	38.29 (10.19)	40.27 (10.85)	49.84 (9.75)	52.73 (10.49)

**No between-group differences were found at baseline, post-training, pre-stressor or during-stressor, all ps > 0.10.*
LSAS is Liebowitz Social Anxiety Scale, STAI-S is Spielberger State-Trait Anxiety Inventory-State.

50 mm in width and 37.5 mm in height. The face photographs were presented with equal distance from the top and bottom of the fixation cross, with a distance of 15 mm between them. The top photograph was positioned 30 mm from the top edge of the screen. The faces were displayed for 17 ms and were then masked by a pair of scrambled neutral faces displayed for 68 ms (see Mogg and Bradley, 2002 for a similar masking procedure). After the masking disappeared, a target probe consisting of either the letter E or F (font Arial, size 14, bold) appeared at the location previously occupied by one of the masks, and remained on the screen until response. Participants had to determine which of the letters appeared by pressing one of two pre-specified buttons on a mouse. The task comprised 128 trials of disgust-neutral pairs and 32 trials of neutral-neutral pairs, for a total of 160 trials, displayed in a random order.

The 128 disgust-neutral trials were counterbalanced with regard to actor identity, disgusted face location (top, bottom), probe location (top, bottom), and probe type (E, F). Attention bias for each participant was calculated by subtracting the mean RT of trials in which the target probe appeared at the disgust face location from the mean RT of trials in which the target appeared at the neutral face location. Positive scores reflect a bias toward threat (threat vigilance), whereas negative scores reflect an attentional bias away from threat (threat avoidance). On neutral–neutral trials target location and type were fully counterbalanced and RTs from these trials were not included in attention bias calculation.

The affective spatial cueing task

Assessing attention bias using the dot-probe task following ABM may reflect only near transfer of the training effect since it relies on the same task demands and stimuli as the ABM training itself. To further test for generalization of potential changes in threat attendance as a function of ABM, we used an affective variant of Posner's spatial cueing task (Stormark et al., 1995; Fox et al., 2001, 2002). In Posner's original task (Posner, 1980), a cue appears in one of two locations, and is followed by a target at the cued location on a majority of the trials (valid cue) and at the alternative location on a minority of the trials (invalid cue). Speeding on valid trials is attributed to the benefits of attentional engagement with the cued location. Slowing on invalid trials is associated with the costs of having to disengage attention from the cued location. Systematic manipulation of the emotional content of cues reveals the effect of cue valence on attention. Studies using this task typically report increased dwelling time on threat invalid cues relative to neutral invalid cues, in anxious relative to non-anxious individuals (Bar-Haim et al., 2007). This is thought to reflect a difficulty in disengaging attention from threat among anxious individuals. To test for far transfer of training effects we used the emotional spatial cuing task in addition to the dot-probe task and also used different stimuli (angry faces rather than disgusted faces). Both disgust and anger expressions constitute threatening cues to socially anxious individuals, and attentional vigilance for both types of stimuli was demonstrated in this population (e.g., Mogg et al., 2004; Pishyar et al., 2004). Here, the emotional cues

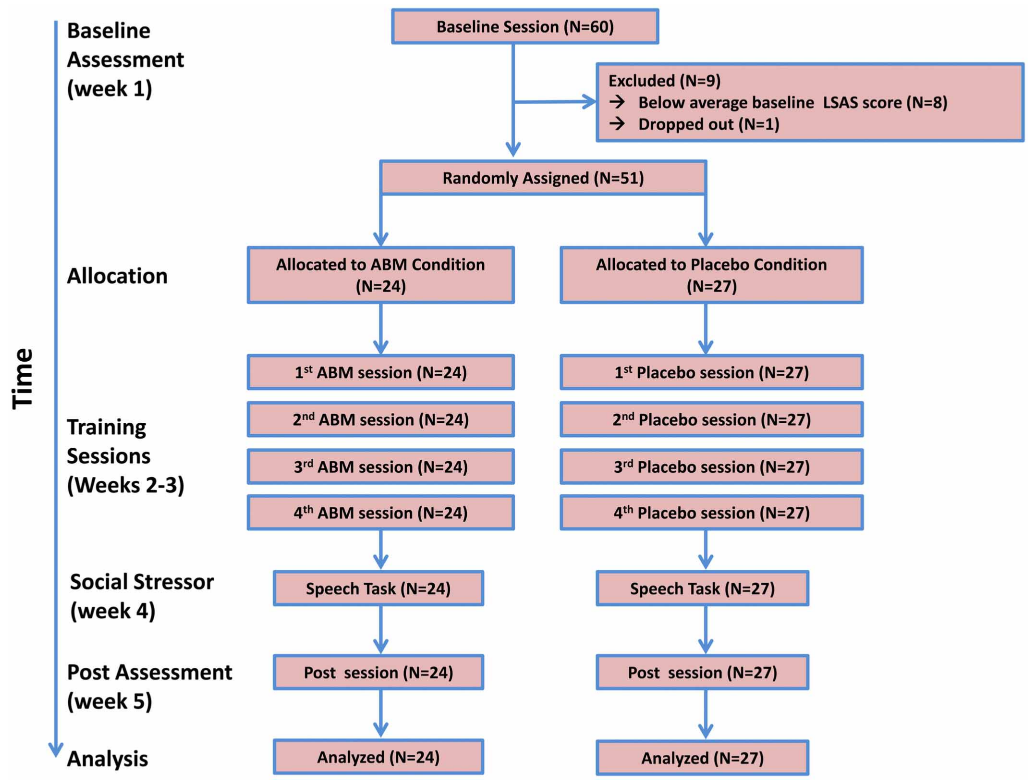

FIGURE 1 | CONSORT diagram and sequence of events in the study.

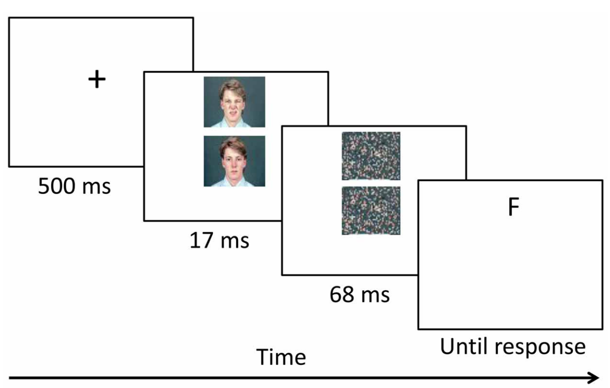

FIGURE 2 | Sequence of events in a subliminal dot-probe trial.

consisted of face photographs of 16 different actors (8 females) taken from the NimStim stimulus set (Tottenham et al., 2009). Two pictures of each actor were selected depicting an angry and a neutral expression. The target was an arrow pointing either up or down. Participants had to determine the arrow's direction by pressing one of two pre-specified buttons on a mouse. Cue and target stimuli were presented inside two dark gray boxes (50 mm × 65 mm) which were displayed continuously to the left and the right of the screen center. Each trial was initiated by a fixation cross presented in the center of the screen for 500 ms. Then, the cue was presented either in the left or right box for 17 ms, and immediately masked by a scrambled neutral face displayed for 68 ms. The target arrow then appeared in either the same box as the cue (valid trials) or the opposite box (invalid trials) and remained on the screen until response. The task comprised 192 trials of which 75% were valid and 25% were invalid. Within each type of trial (valid/invalid), cue type (neutral/angry), target location (left/right), and target type (pointing up/pointing down) were fully counterbalanced. Throughout the task each actor's photographs appeared a total of 12 times—6 times with an angry expression and 6 times with a neutral expression. Threat engagement was calculated as mean RT for valid neutral trials minus mean RT for valid threat trials. Positive engagement scores reflect attentional bias toward threat (threat engagement), whereas negative engagement scores reflect an attentional bias away from threat (threat avoidance). Threat disengagement was calculated as mean RT for invalid threat trials minus mean RT for invalid neutral trials. Positive disengagement scores are considered to reflect a difficulty in disengaging attention from threat stimuli.

ATTENTION BIAS MODIFICATION (ABM)

The ABM version of the dot-probe task displayed the same stimuli as those used for threat bias assessment except that target probes (E, F) appeared only at the location previously occupied by neutral faces with the aim of implicitly establishing these as a predictive cue for the location of the probe. The placebo control group received the same number and type of trials as the ABM group but in a fully counterbalanced manner as was done during threat bias assessment. Thus, no attention modification was expected in the placebo control group.

VISUAL MASKING EFFICACY TEST

To ensure that participants were not consciously aware of the emotional valence of the masked faces, an objective detection task was used (Merikle et al., 2001). This two-alternative forced choice task comprised 32 trials. Stimuli were pairs of identical face pictures (i.e., two neutral faces or two disgusted faces) taken from those presented in the assessment version of the dot-probe task. In each trial, a face pair was presented and masked in the same manner as in the dot-probe task. Participants were told that half of the trials contain a pair of identical faces featuring a negative valence, whereas the other half contains a pair of identical neutral faces, and had to indicate via button press whether the faces in each trial were "neutral" or "negative." A 95% confidence interval was calculated to reflect chance level performance.

SOCIAL STRESS INDUCTION TASK

The social stress induction task was similar to the one used by Amir et al. (2008). Participants were asked to choose one of three discussion topics (using nuclear energy to produce electricity, school uniform, or toll roads) and prepare a 5-minute speech concerning claims in favor of and against the selected topic. Participants were informed that their speech would be videotaped and later evaluated for quality by the research staff. During the speech task an unfamiliar male experimenter was present in the room, provided instructions, and operated the video camera.

PROCEDURE

Over a period of five weeks, participants completed a baseline assessment session, four attention training/placebo sessions, a stress induction session, and a final evaluation session (see CONSORT diagram **Figure 1**). The baseline assessment session lasted 25 min during which participants completed the STAI-S, LSAS, and the dot-probe and affective spatial cueing tasks. All computerized tasks were run in a darkened room, on a 17-inch-screen laptop computer (Lenovo R61i), using E-Prime software. Participants were seated at a viewing distance of 80 cm from the monitor. Following the assessment session participants received four training sessions according to their group assignment (two sessions on nonconsecutive days per week, over two weeks). Each training session lasted approximately 10 min. The sixth session, conducted 4–7 days following the last training session, was dedicated to testing the effects of ABM on stress vulnerability using the social stress induction task. This session took place in a different room than the room of the training sessions. The male experimenter administering this session was unfamiliar to the participants and blind to all aspects and purposes of the study. Participants completed the STAI-S in a waiting room. The experimenter then invited participants to enter the testing room where the social stress procedure was conducted. Following 5 min of speech preparation participants were asked to step up to a marked spot in front of the camera and deliver their speech. Two minutes into their speech, the experimenter temporarily paused the task and asked participants to complete the STAI-S again. The experimenter made it clear that the speech will be resumed shortly after completion of the questionnaire. Following one additional minute of speech participants were halted and thanked. Stress vulnerability was indexed as the change between pre- and during-stressor STAI-S. The seventh and final session was held in the following week and took place in the same room as the training sessions. Each participant performed the same dot-probe and affective spatial cueing tasks as in the baseline session. Then, participants completed the test of visual masking efficacy followed by completion of the LSAS and the STAI-S.

DATA ANALYSIS

Trials with RTs shorter than 150 ms or longer than 2000 ms, or incorrect response were excluded. Then, for each participant, mean RT per trial type was calculated, and trials with RTs deviating by more than 2.5 SDs from the mean were further excluded. This resulted in the removal of an average of 6% of all trials per participant.

The effect of subliminal ABM on attention was assessed for bias scores on the dot-probe task and for RTs in the affective spatial cueing task. Dot-probe attention bias scores were subjected to a 2×2 repeated-measures ANOVA with Group (ABM, placebo) as a between-subjects factor and Time (baseline, post-training) as a repeated within-subject factor. Response times on the affective spatial cueing task were submitted to a $2 \times 2 \times 2 \times 2$ ANOVA with Group (ABM, placebo) as a between-subjects factor, and Time (baseline, post-training), Cue Validity (valid, invalid), and Cue Valence (threat, neutral) as repeated within-subject factors.

To examine the effect of subliminal ABM on trait social anxiety levels, total social anxiety scores from the LSAS were submitted to a 2×2 ANOVA with Group (ABM, placebo) as a between-subjects factor and Time (baseline, post-training) as a repeated within-subject factor. To examine the effect of subliminal ABM on vulnerability to social stress, a repeated-measures ANOVA was conducted on STAI-S scores before and during- the stressor task. Group (ABM, placebo) served as a between-subjects factor and Stressor-Phase (pre-stressor, during-stressor) served as a repeated within-subject factor.

Because recent studies suggest that baseline attention bias toward threat may predict supraliminal ABM training efficacy (Amir et al., 2011), as well as cognitive-behavioral treatment efficacy (Waters et al., 2012), we explored this possibility in the current subliminal ABM study. We conducted two *post-hoc* analyses to test whether baseline vigilance or avoidance (attention bias toward or away from threat) modulated the effect of subliminal ABM on social anxiety and stress vulnerability. First, following Waters et al. (2012), we divided the participants to two groups based on whether they had a bias toward threat ("attenders," attention bias > 0; $n = 29$) or a bias away from threat ("avoiders," attention bias < 0; $n = 21$) at baseline. This new dichotomous variable was entered as an additional between-subjects factor in the above described primary ANOVAs. Second, following Amir et al. (2011), we regressed baseline attention bias as a continuous predictor, along with training group (ABM/Placebo) (step 1) and their interaction term (step 2) on state anxiety (STAI-S) change score from pre- to during the stress induction episode. The same regression model was also applied to change in trait social anxiety (LSAS) from pre- to post ABM/Placebo.

RESULTS

VISUAL MASKING EFFICACY TEST

All participants but one performed the task at chance level (mean = 50.12% correct, $SD = 8.12$), indicating that the masking procedures were effective and that participants were unaware of the affective valence of the faces. One participant had an above-threshold accuracy performance (72% correct). All the analyses reported exclude the data from this participant. When analyses were conducted including this particular subject, no changes were noted in the results pattern.

BASELINE MEASUREMENTS

Means and SDs for LSAS, STAI-S, and RTs and bias scores on the dot-probe and affective spatial cueing tasks at baseline by training condition are provided in **Table 1** (left panel). None of these measures significantly differed between the ABM and Placebo-Control groups (all $ps > 0.19$). Attention bias in the dot probe task as well as engagement and disengagement biases in the affective spatial cueing task were not significantly different than zero neither in the ABM group nor in the Control group (all $ps > 0.15$).

POST-TRAINING MEASUREMENTS

Means and SDs for LSAS, STAI-S, and RTs and bias scores on the dot-probe and affective spatial cueing tasks at post-training by training condition are provided in **Table 1** (right panel).

Change in attention threat bias

Dot-probe. This analysis yielded no significant main or interaction effects, indicating no detectable changes in attention bias scores from pre- to post-training, all $ps > 0.68$.

Affective spatial cuing task. RTs to invalidly cued trials were longer than RTs to validly cued trials reflecting the classic Posner validity effect, $F_{(1, 48)} = 187.13$, $p < 0.0001$, $\eta_p^2 = 0.80$. In addition, a main effect of Time was found, reflecting faster overall RTs following ABM/Placebo, $F_{(1, 48)} = 6.39$, $p < 0.05$, $\eta_p^2 = 0.12$. No other main or interaction effects reached statistical significance.

Trait social anxiety (LSAS)

This analysis yielded no significant main or interaction effects, indicating that subliminal ABM did not affect self-reported trait social anxiety (LSAS), all $ps > 0.41$.

Social stress vulnerability

A main effect of Stressor-Phase was found, $F_{(1, 48)} = 54.86$, $p < 0.0001$, $\eta_p^2 = 0.53$, demonstrating that the stressor task significantly increased state anxiety levels from pre-stressor (mean = 39.32, $SD = 10.48$) to during-stressor (mean = 51.34, $SD = 10.14$). No other main or interaction effects reached statistical significance, all $ps > 0.32$.

SECONDARY *POST-HOC* ANALYSES—TESTING THE EFFECT OF BASELINE ATTENTION BIAS

Baseline bias as a dichotomous factor

Means and SDs of all baseline and post-training measurements for baseline attenders and avoiders are presented in **Table A1** (see appendix). The average baseline attention bias scores in the attenders (12 ms, $SD = 9$) and the avoiders (−18 ms, $SD = 12$) groups were each significantly different from zero, $t_{(28)} = 7.44$, $p < 0.0001$ and $t_{(20)} = -6.63$, $p < 0.0001$, respectively. There were no significant differences in baseline bias scores between ABM and control participants neither in the attenders nor in the avoiders groups (all $ps > 0.6$, for means and SDs see **Table 2**).

Adding the baseline attention bias (toward or away from threat) as a factor to all analyses produced two significant interaction effects: first, when testing for effects of ABM on attention bias using the dot-probe task, a Time-by-Baseline Bias interaction effect emerged, $F_{(1, 46)} = 24.27$, $p < 0.0001$, $\eta_p^2 = 0.35$. Both participants who had an attention bias toward threat and participants who had an attention bias away from threat at baseline (means = 12.31 and −17.97, SDs = 8.91 and 12.42, respectively) converged toward having no bias following ABM/Placebo (means = 0.44 and −0.66, SDs = 18.43 and 15.13, respectively).

The second significant interaction was related to the effect of ABM on stress vulnerability. STAI-S means and SDs before and during the social stressor task are presented in **Table 2**. There was a significant three-way Stressor-Phase-by-Group-by-Baseline Bias interaction effect, $F_{(1, 46)} = 12.31$, $p < 0.001$, $\eta_p^2 = 0.21$. To explicate this interaction, two ANOVAs of Group (ABM, placebo) by Stressor-Phase (pre-stressor, during-stressor) were conducted, one for participants who had attention bias away from threat at baseline (avoiders) and one for participants who had attention bias toward threat at baseline (attenders). For threat avoiders, those who received ABM showed larger elevation in state anxiety in response to the stressor task relative to their counterparts in the placebo training group. However, this interaction was non-significant, $F_{(1, 19)} = 3.89$, $p = 0.063$.

Table 2 | Means and SDs of baseline attention bias and state anxiety (STAI-S) pre- and during-stressor, for baseline attenders and avoiders by training group.

	Baseline attenders		Baseline avoiders	
	ABM ($N = 15$)	**Placebo-Control ($N = 14$)**	**ABM ($N = 9$)**	**Placebo-Control ($N = 12$)**
Baseline attention bias	12 (8)	13 (10)	−19 (16)	−17 (9)
STAI-S				
Pre-Stressor	39.33 (7.91)	36.65 (8.26)	36.56 (13.55)	44.50 (12.27)
During-Stressor	47.60 (9.72)	54.71 (9.93)	53.57 (9.12)	50.42 (11.07)

For threat attenders, however, a significant Stressor-Phase-by-Group interaction effect was found, $F_{(1, 27)} = 10.36$, $p < 0.005$, $\eta_p^2 = 0.28$. Follow-up contrasts indicated that both groups (ABM and Placebo) showed significant increases in state anxiety from before-to-during stressor, both ps < 0.001. Additional between-group contrasts revealed that the two groups did not differ on STAI-S scores before stress induction, $t_{(27)} = -0.89$, $p = 0.38$. Interestingly, the ABM group showed lower STAI-S scores relative to the placebo group during stress, $t_{(27)} = 1.95$, $p = 0.062$. This non-significant trend may suggest that among those who attended toward threat at baseline, those who received ABM were less vulnerable to the stressor (**Figure 3**).

Baseline bias as a continuous factor

The estimated coefficients and significance levels for the two steps in the regression model are shown in **Table 3**. The overall regression model significantly explained 31 percent of the variance in state anxiety change due to stress induction, $F_{(3, 46)} = 6.80$, $p < 0.001$. This model explained significantly and substantially more variance in stress-related anxiety change as compared to the model considering only baseline attention bias and group as single predictors, without taking into account their interaction. Specifically, when not considering the interaction in the model, ABM/Placebo Group did not predict state anxiety change. Baseline attention bias predicted state anxiety change at a trend level of significance with greater baseline threat bias predicting greater elevations in state anxiety following stress induction. Importantly, the interaction term between baseline attention bias and ABM/Placebo group significantly predicted state anxiety change. Follow-up simple slope analyses demonstrated that for the Placebo-Control group the slope coefficient was positive and significantly different from zero, $B = 0.46$, $t_{(24)} = 4.55$, $p < 0.0001$, suggesting that in this group, individuals with greater attention bias to threat at baseline demonstrated larger elevations of anxiety during the stress task. In contrast, for the ABM group the slope coefficient was not significantly different from zero, $B = -0.16$, $t_{(22)} = -1.36$, $p > 0.15$ (**Figure 4**).

The regression model predicting change in trait social anxiety (LSAS) from pre- to post-training was non-significant ($p > 0.8$).

DISCUSSION

The present study is the first to report a randomized controlled ABM trial using subliminally-presented stimuli in high socially-anxious individuals. The aim of the study was to examine whether subliminal ABM training away from threat faces

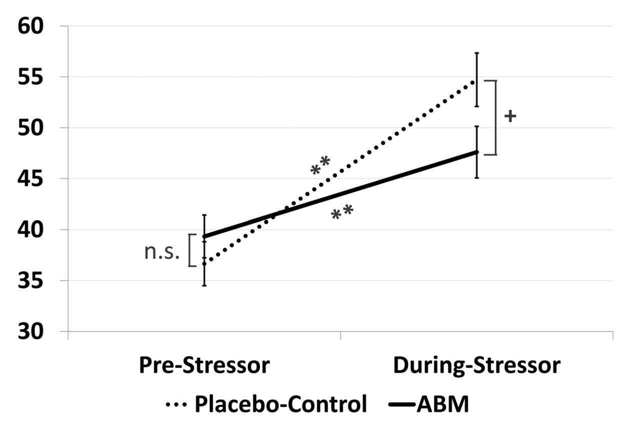

FIGURE 3 | State Anxiety Scores (STAI-S) and standard error bars for participants with baseline threat vigilance pre- and during the social stressor task by attention training condition. $^{**}p < 0.0001$; $+$ $p = 0.06$.

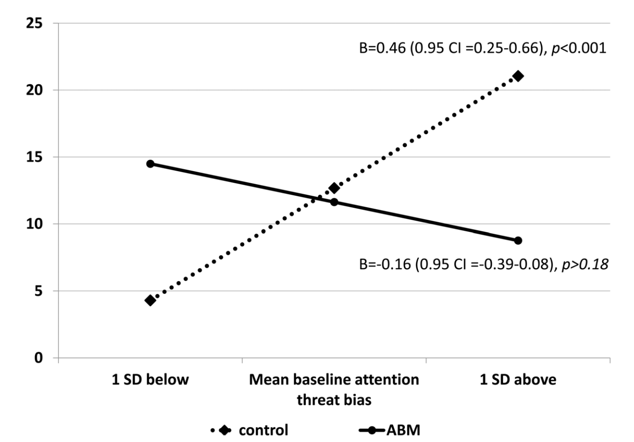

FIGURE 4 | Simple slope analyses: the estimated change in state anxiety from pre to during the stressor task, as a function of the interaction between baseline attention bias and training group (ABM/Placebo-control).

Table 3 | Estimated coefficients, standard errors, and 0.95 confidence intervals for predictors in the two steps of the regression model predicting stressor-related anxiety change.

	Predictor	B	SE	*t*	95% CI	R^2	ΔR^2
Step 1	Baseline attention bias	0.15+	0.09	1.74	−0.02 – 0.33	0.06	
	Training group	−1.06	3.18	−0.34	−7.45 – 5.33		
Step 2	Baseline attention bias	0.46**	0.11	4.27	0.24 – 0.67	0.31	0.25**
	Training group	−1.30	2.76	−0.47	−6.85 – 4.26		
	Baseline attention bias × Training group	−0.61**	0.15	−4.04	−0.92 – −0.31		

$^{+}p = 0.089$; $^{**}p < 0.001$. Training group = ABM/Placebo-control groups. B = unstandardized estimated coefficient. SE = standard error. CI = confidence interval.

was effective in reducing levels of social anxiety and social stress vulnerability in socially-anxious students. In our effort to accomplish this aim, we relied on commonly used ABM and attention bias measurement methods that have proved effective in supraliminal ABM research in similar populations. However, despite this methodological effort and in contrast to our expectations, the subliminal ABM used in the current study did not induce detectable change in threat-related attention, neither on the dot-probe task (near transfer) nor on the affective spatial cueing task (far transfer). We were also unable to find an effect of ABM on self-reported trait social anxiety.

There are various potential explanations for the null-findings which could be broadly classified into four general types: (a) that subliminal ABM is inherently ineffective for changing preconscious attention patterns in anxious individuals; (b) that the specific subliminal ABM protocol used here was not effective in inducing the expected change in attention patterns; (c) that subliminal ABM did in fact modify attentional patterns, but our measurement precision failed to detect this change; and (d) that subliminal attention processes are related to anxiety only in a sub-group of socially anxious individuals, those who demonstrate threat-related attention bias at baseline. Because our sample as a whole did not demonstrate a measureable attention bias toward subliminal threat at baseline this possibility was tested in *post-hoc* analyses looking at the role of baseline threat bias in anxiety reduction as a function of ABM. The theoretical and practical implications of each of the above-listed options are distinct in important ways. Next we discuss the implications of each of these possibilities.

Subliminal ABM could be inherently ineffective in inducing change in preconscious attention patterns because the relevant neuro-cognitive mechanisms supporting this process might be less malleable to change by ABM as compared to processes occurring within perceptual awareness. Specifically, subliminal threat detection typically involves sub-cortical structures such as the amygdala, one of the core components in danger detection and evaluation (Ledoux, 2000; Amaral, 2002), whose function relies, at least in part, on automatic, rapid-responding neural architecture (Ohman and Mineka, 2001; Ohman, 2005; Adolphs and Spezio, 2006). If preconscious attention patterns are indeed less malleable to change, two important conclusions may be derived: practically, there may be no reason to invest further efforts in subliminal ABM methods. Theoretically, one may speculate that consistent failure to modify attentional patterns using subliminal ABM is consistent with the notion that modification of threat bias by ABM and the associated reduction in anxiety are mediated by later processes of attention control rather than by automatic attention capture (Browning et al., 2010; Eldar and Bar-Haim, 2010; Heeren et al., 2013).

A second possible explanation for the current null results is that the specific subliminal ABM protocol used here was not sufficiently effective to induce the expected change in attention patterns. For example, it might be that trying to change early preconscious processes using subliminal ABM requires more training sessions, more trials per session, different stimuli, or different masking procedure. If so, more experimental research is needed to unveil these parameters that individually or together obscure the expected effects.

Third, it may be considered that the subliminal ABM training did in fact influence attentional patterns, but our measurement tools failed to detect this change. This could be due to the relatively long time interval that elapsed from the end of training to the post-training measurement of attention bias, or due to the effects of using subliminal stimuli. For example, one may consider the possibility that consciously perceived threat is necessary for ABM effects on attention to surface in measurement. In supraliminal ABM protocols the presence of threat stimuli is consciously perceived throughout all assessment and practice sessions. In contrast, in the current study conscious perception of threat never occurred neither during training nor during threat bias assessments. Future studies may consider measuring change in threat bias using supraliminal presentations even when ABM is subliminally delivered.

Finally, the finding of reduced stress vulnerability following subliminal ABM in participants who demonstrated attention bias toward threat at baseline may offer a clue that for a sub-group of participants there was in fact some effect of subliminal ABM on stress vulnerability. This finding is in accord with recently reported results from supraliminal ABM in patients diagnosed with general social phobia (Amir et al., 2011). In Amir et al. (2011), patients in the ABM condition who had greater threat bias at baseline displayed significantly larger reductions in clinician-rated social anxiety symptoms relative to their counterparts in the placebo condition. ABM did not differ from placebo in patients who did not show threat bias at baseline. These findings from Amir et al. (2011) and the present finding are also in line with the basic rationale for ABM procedures. That is, that pre-treatment threat bias is the target for ABM; hence the absence of such bias might render ABM ineffective. A similar rationale was offered in a randomized controlled ABM study with clinically anxious children, which applied a baseline bias toward threat as an inclusion criterion for participation (Eldar et al., 2012). The current finding along with previous results highlights the possibility that ABM procedures may be beneficial to a specific sub-group of socially-anxious individuals characterized by attention bias toward threatening cues at baseline. If proved reliable, such specificity in predicting treatment efficacy may be ultimately applied to personalize anxiety treatment. However, it is important to keep in mind that, at least in the present study, this finding was part of a *post-hoc* exploration and could be merely incidental. It is also important to note that attention bias in both threat attenders and threat avoiders converged toward zero at post-training, thus could simply reflect regression to the mean. Future studies may benefit from designs that specifically and a priori hypothesize about the role of baseline threat bias in the clinical response to ABM.

Despite the discouraging findings with subliminal ABM thus far, the potential of this intervention should not be dismissed prematurely. If future studies could substantiate evidence that subliminal training of threat-related attention may have anxiolytic effects, it would point to the potential of ABM to target components of threat processing that function outside perceptual awareness. Such specific processes may occur independently and within different brain networks than processes activated by consciously-perceived threats (Etkin et al., 2004; Li et al., 2007). Future studies may utilize brain imaging techniques to directly examine and compare the underlying neuro-cognitive mechanisms affected by subliminal and supraliminal ABM. If indeed subliminal and supraliminal ABM methods influence different neuro-cognitive mechanisms related to anxiety, they may possess additive therapeutic values, and may prove more efficient if delivered as a combined treatment procedure. This possibility should be determined in future research directly comparing subliminal ABM, supraliminal ABM, and a combination of the two.

Interpretation of the results of the present study should be considered in light of important limitations. First, the participants in the present study were not clinically-diagnosed with social phobia, but rather represent a sample of undergraduate students who self-reported high levels of social anxiety. While the use of analog populations typically provides an opportunity to test preliminary treatment-related ideas, in the current study it might have also limited the potential to detect anxiety-related effects of subliminal ABM training. Future studies with clinically-diagnosed populations could further test the efficacy of subliminal ABM. Second, the present sample may not be large enough to detect existing effects if these are relatively small. It should be noted, however, that the detected effect of subliminal ABM on social stress vulnerability within the threat-attenders sub-group is quite robust considering the small sample size. Third, the fact that attention bias toward subliminal threat was not significantly different from zero in the current sample could be considered a limitation that may have hampered the possibility to detect attentional and anxiety-related changes. Considering the small-to-medium effect size of the threat bias phenomenon in general, it is not uncommon that a single study will not be able to find anxiety-related attention bias (Bar-Haim et al., 2007). Furthermore, the effect is many times reported for between group designs comparing anxious individuals to non-anxious controls, while in the current study there were only high-anxious participants. One way to probe this shortcoming is to analyze the results referring to participants who actually showed threat bias at baseline (as was done here using *post-hoc* analyses). While these analyses seem to support the notion that baseline threat bias may be important for ABM success, caution should be taken in the interpretation of these *post-hoc* findings, particularly those based on the dichotomous split to attenders and avoiders. This particular analysis relied on very small group sizes and also suffers from the possibility that some group members may not truly deviate from zero bias. These concerns may be alleviated to some extent by the supportive findings relying on baseline attention bias as a continuous variable in the regression analyses and should be explored in future research.

In conclusion, the current study is mainly offering null results of subliminal ABM, as we were unable to show direct effects of subliminal ABM training on attention patterns or anxiety levels. Nevertheless, we think it may be important for the ABM research community to be exposed to these findings so that both an open discussion of the issue could be advanced and future studies could use this failure as a stepping stone for their ABM designs. The current study is the first to report null results for subliminal ABM conducted with an anxious population and it corresponds with recently published null effects of supraliminal ABM (Carlbring et al., 2012; Bunnell et al., 2013; Neubauer et al., 2013). We hope that researchers would continue to share both null- and positive-findings concerning ABM in order to advance understanding and experimentation in this field. In the same vein, we also thought it is worthwhile to report the *post-hoc* analyses suggesting that subliminal ABM training may carry some potential to reduce social stress vulnerability, and that baseline threat bias may serve as a marker for such efficacy.

REFERENCES

Adolphs, R., and Spezio, M. (2006). Role of the amygdala in processing visual social stimuli. *Prog. Brain Res.* 156, 363–378. doi: 10.1016/S0079-6123(06)56020-0

Amaral, D. G. (2002). The primate amygdala and the neurobiology of social behavior: implications for understanding social anxiety. *Biol. Psychiatry* 51, 11–17. doi: 10.1016/S0006-3223(01)01307-5

Amir, N., Beard, C., Taylor, C. T., Klumpp, H., Elias, J., Bums, M., et al. (2009). Attention training in individuals with generalized social phobia: a randomized controlled trial. *J. Consult. Clin. Psychol.* 77, 961–973. doi: 10.1037/a0016685

Amir, N., Taylor, C. T., and Donohue, M. C. (2011). Predictors of response to an attention modification program in generalized social phobia. *J. Consult. Clin. Psychol.* 79, 533–541. doi: 10.1037/a0023808

Amir, N., Weber, G., Beard, C., Bomyea, J., and Taylor, C. T. (2008). The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals. *J. Abnorm. Psychol.* 117, 860–868. doi: 10.1037/a0013445

Bar-Haim, Y. (2010). Research review: attention bias modification (ABM): a novel treatment for anxiety disorders. *J. Child Psychol. Psychiatry* 51, 859–870. doi: 10.1111/j.1469-7610.2010.02251.x

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., and Van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol. Bull.* 133, 1–24. doi: 10.1037/0033-2909.133.1.1

Bar-Haim, Y., Morag, I., and Glickman, S. (2011). Training anxious children to disengage attention from threat: a randomized controlled trial. *J. Child Psychol. Psychiatry* 52, 861–869. doi: 10.1111/j.1469-7610.2011.02368.x

Beard, C. (2011). Cognitive bias modification for anxiety: current evidence and future directions. *Expert Rev. Neurother.* 11, 299–311. doi: 10.1586/ern.10.194

Browning, M., Holmes, E. A., and Harmer, C. J. (2010). The modification of attentional bias to emotional information: a review of the techniques, mechanisms, and relevance to emotional disorders. *Cogn. Affect. Behav. Neurosci.* 10, 8–20. doi: 10.3758/CABN.10.1.8

Bunnell, B. E., Beidel, D. C., and Mesa, F. (2013). A randomized trial of attention training for generalized social phobia: does attention training change social behavior? *Behav. Ther.* doi: 10.1016/j.beth.2013.04.010. [Epub ahead of print].

Carlbring, P., Apelstrand, M., Sehlin, H., Amir, N., Rousseau, A., Hofmann, S. G., et al. (2012). Internet-delivered attention bias modification training in individuals with social anxiety disorder – a double blind randomized controlled trial. *BMC Psychiatry* 12:66. doi: 10.1186/1471-244X-12-66

Eldar, S., Apter, A., Lotan, D., Edgar, K. P., Naim, R., Fox, N. A., et al. (2012). Attention bias modification treatment for pediatric anxiety disorders: a randomized controlled trial. *Am. J. Psychiatry* 169, 213–220. doi: 10.1176/appi.ajp.2011.11060886

Eldar, S., and Bar-Haim, Y. (2010). Neural plasticity in response to attention training in anxiety. *Psychol. Med.* 40, 667–677. doi: 10.1017/S0033291709990766

Eldar, S., Ricon, T., and Bar-Haim, Y. (2008). Plasticity in attention: implications for stress response in children. *Behav. Res. Ther.* 46, 450–461. doi: 10.1016/j.brat.2008.01.012

Etkin, A., Klemenhagen, K. C., Dudman, J. T., Rogan, M. T., Hen, R., Kandel, E. R., et al. (2004). Individual differences in trait anxiety predict the response of the basolateral amygdala to unconsciously processed fearful faces. *Neuron* 44, 1043–1055. doi: 10.1016/j.neuron.2004.12.006

Fox, E. (2002). Processing emotional facial expressions: the role of anxiety and awareness. *Cogn. Affect. Behav. Neurosci.* 2, 52–63. doi: 10.3758/CABN.2.1.52

Fox, E., Cahill, S., and Zougkou, K. (2010). Preconscious processing biases predict emotional reactivity to stress. *Biol. Psychiatry* 67, 371–377. doi: 10.1016/j.biopsych.2009.11.018

Fox, E., Russo, R., Bowles, R., and Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *J. Exp. Psychol. Gen.* 130, 681–700. doi: 10.1037/0096-3445.130.4.681

Fox, E., Russo, R., and Dutton, K. (2002). Attentional bias for threat: evidence for delayed disengagement from emotional faces. *Cogn. Emot.* 16, 355–379. doi: 10.1080/02699930143000527

Fresco, D. M., Coles, M. E., Heimberg, R. G., Liebowitz, M. R., Hami, S., Stein, M. B., et al. (2001). The Liebowitz Social Anxiety Scale: a comparison of the psychometric properties of self-report and clinician-administered formats. *Psychol. Med.* 31, 1025–1035. doi: 10.1017/S0033291701004056

Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. A., Leibenluft, E., et al. (2010). Attention bias modification treatment: a meta-analysis toward the establishment of novel treatment for anxiety. *Biol. Psychiatry* 68, 982–990. doi: 10.1016/j.biopsych.2010.07.021

Hallion, L. S., and Ruscio, A. M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychol. Bull.* 137, 940–958. doi: 10.1037/a0024355

Heeren, A., De Raedt, R., Koster, E. H. W., and Philippot, P. (2013). The (neuro)cognitive mechanisms behind attention bias modification in anxiety: proposals based on theoretical accounts of attentional bias. *Front. Hum. Neurosci.* 7:119. doi: 10.3389/fnhum.2013.00119

Heeren, A., Lievens, L., and Philippot, P. (2011). How does attention training work in social phobia: disengagement from threat or re-engagement to non-threat? *J. Anxiety Disord.* 25, 1108–1115. doi: 10.1016/j.janxdis.2011.08.001

Heeren, A., Reese, H. E., McNally, R. J., and Philippot, P. (2012). Attention training toward and away from threat in social phobia: effects on subjective, behavioral, and physiological measures of anxiety. *Behav. Res. Ther.* 50, 30–39. doi: 10.1016/j.brat.2011.10.005

Klumpp, H., and Amir, N. (2010). Preliminary study of attention training to threat and neutral faces on anxious reactivity to a social stressor in social anxiety. *Cogn. Ther. Res.* 34, 263–271. doi: 10.1007/s10608-009-9251-0

Koster, E. H. W., Fox, E., and MacLeod, C. (2009). Introduction to the special section on cognitive bias modification in emotional disorders. *J. Abnorm. Psychol.* 118, 1–4. doi: 10.1037/a0014379

Ledoux, J. E. (2000). Emotion circuits in the brain. *Annu. Rev. Neurosci.* 23, 155–184. doi: 10.1146/annurev.neuro.23.1.155

Levin, J. B., Maron, S., Gur, S., Wechter, D., and Hermesh, H. (2002). Psychometric properties and three proposed subscales of a self-report version of the Liebowitz Social Anxiety Scale translated into Hebrew. *Depress. Anxiety* 16, 143–151. doi: 10.1002/da.10064

Li, W., Zinbarg, R. E., and Paller, K. A. (2007). Trait anxiety modulates supraliminal and subliminal threat: brain potential evidence for early and late processing influences. *Cogn. Affect. Behav. Neurosci.* 7, 25–36. doi: 10.3758/CABN.7.1.25

Liebowitz, M. R. (1987). Social phobia. *Mod. Probl. Pharmacopsychiatry* 22, 141–173.

MacLeod, C., and Hagan, R. (1992). Individual-differences in the selective processing of threatening information, and emotional responses to a stressful life event. *Behav. Res. Ther.* 30, 151–161. doi: 10.1016/0005-7967(92)90138-7

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., and Holker, L. (2002). Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. *J. Abnorm. Psychol.* 111, 107–123. doi: 10.1037/0021-843X.111.1.107

Mathews, A., and MacLeod, C. (1986). Discrimination of threat cues without awareness in anxiety-states. *J. Abnorm. Psychol.* 95, 131–138. doi: 10.1037/0021-843X.95.2.131

Mathews, A., and MacLeod, C. (2002). Induced processing biases have causal effects on anxiety. *Cogn. Emot.* 16, 331–354. doi: 10.1080/02699930143000518

Matsumoto, D., and Ekman, P. (1988). *The Japanese and Caucasian Facial Expressions of Emotion (JACFEE) and Neutrals (JACNeuF) [CDs].* San Francisco, CA: Department of Psychology, San Francisco State University.

Mennin, D. S., Fresco, D. M., Heimberg, R. G., Schneier, F. R., Davies, S. O., and Liebowitz, M. R. (2002). Screening for social anxiety disorder in the clinical setting: using the Liebowitz Social Anxiety Scale. *J. Anxiety Disord.* 16, 661–673. doi: 10.1016/S0887-6185(02)00134-2

Merikle, P. M., Smilek, D., and Eastwood, J. D. (2001). Perception without awareness: perspectives from cognitive psychology. *Cognition* 79, 115–134. doi: 10.1016/S0010-0277(00)00126-8

Mogg, K., and Bradley, B. P. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behav. Res. Ther.* 40, 1403–1414. doi: 10.1016/S0005-7967(02)00017-7

Mogg, K., Bradley, B. P., Williams, R., and Mathews, A. (1993). Subliminal processing of emotional information in anxiety and depression. *J. Abnorm. Psychol.* 102, 304–311. doi: 10.1037/0021-843X.102.2.304

Mogg, K., Philippot, P., and Bradley, B. P. (2004). Selective attention to angry faces in clinical social phobia. *J. Abnorm. Psychol.* 113, 160–165. doi: 10.1037/0021-843X.113.1.160

Neubauer, K., Von Auer, M., Murray, E., Petermann, F., Helbig-Lang, S., and Gerlach, A. L. (2013). Internet-delivered attention modification training as a treatment for social phobia: a randomized controlled trial. *Behav. Res. Ther.* 51, 87–97. doi: 10.1016/j.brat.2012.10.006

Ohman, A. (2005). The rote of the amygdala in human fear: automatic detection of threat. *Psychoneuroendocrinology* 30, 953–958. doi: 10.1016/j.psyneuen.2005.03.019

Ohman, A., and Mineka, S. (2001). Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychol. Rev.* 108, 483–522. doi: 10.1037/0033-295X.108.3.483

Ohman, A., and Soares, J. J. F. (1994). 'Unconscious anxiety': phobic responses to masked stimuli. *J. Abnorm. Psychol.* 103, 231–240. doi: 10.1037/0021-843X.103.2.231

Pishyar, R., Harris, L. M., and Menzies, R. G. (2004). Attentional bias for words and faces in social anxiety. *Anxiety Stress Coping* 17, 23–36. doi: 10.1080/10615800310001601458

Posner, M. I. (1980). Orienting of attention. *Q. J. Exp. Psychol.* 32, 3–25. doi: 10.1080/00335558008248231

Rytwinski, N. K., Fresco, D. M., Heimberg, R. G., Coles, M. E., Liebowitz, M. R., Cissell, S., et al. (2009). Screening for social anxiety disorder with the self-report version of the Liebowitz Social Anxiety Scale. *Depress. Anxiety* 26, 34–38. doi: 10.1002/da.20503

Schmidt, N. B., Richey, J. A., Buckner, J. D., and Timpano, K. R. (2009). Attention training for generalized social anxiety disorder. *J. Abnorm. Psychol.* 118, 5–14. doi: 10.1037/a0013643

See, J., MacLeod, C., and Bridle, R. (2009). The reduction of anxiety vulnerability through the modification of attentional bias: a real-world study using a home-based cognitive bias modification procedure. *J. Abnorm. Psychol.* 118, 65–75. doi: 10.1037/a0014377

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., and Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Stormark, K. M., Nordby, H., and Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: behavioral and ERP data. *Cogn. Emot.* 9, 507–523. doi: 10.1080/02699939508408978

Teichman, Y., and Melinic, H. (1979). *STAI and STAIC – Hebrew Guidlines* *for the Tester*. Tel Aviv, Israel: Tel Aviv University.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., et al. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Res.* 168, 242–249. doi: 10.1016/j.psychres.2008.05.006

Tsunoda, T., Yoshino, A., Furusawa, T., Miyazaki, M., Takahashi, Y., and Nomura, S. (2008). Social anxiety predicts unconsciously provoked emotional responses to facial expression. *Physiol. Behav.* 93, 172–176. doi: 10.1016/j.physbeh.2007.08.012

van den Hout, M., Tenney, N., Huygens, K., Merckelbach, H., and Kindt, M. (1995). Responding to subliminal threat cues is related to trait anxiety and emotional vulnerability: a successful replication of MacLeod and Hagan (1992). *Behav. Res. Ther.* 33, 451–454. doi: 10.1016/0005-7967(94)00062-O

Waters, A. M., Mogg, K., and Bradley, B. P. (2012). Direction of threat attention bias predicts treatment outcome in anxious children receiving cognitive-behavioural therapy. *Behav. Res. Ther.* 50, 428–434. doi: 10.1016/j.brat.2012.03.006

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APPENDIX

Table A1 | Means and SDs of baseline, post-training, pre-stressor, and during-stressor measurements for baseline attenders and avoiders by training group.

	Baseline attenders			Baseline avoiders		
	ABM (N = 15)	**Placebo-Control (N = 14)**	**Total (N = 29)**	**ABM (N = 9)**	**Placebo-Control (N = 12)**	**Total (N = 21)**
Gender (F/M)	12/3	12/2	24/5	8/1	8/4	16/5
Age	22.93 (1.83)	22.21 (1.31)	22.59 (1.62)	23 (2.24)	22.67 (1.37)	22.81 (1.75)
BASELINE MEASUREMENTS						
LSAS score	54.60 (12.59)	58.71 (22.10)	56.59 (17.62)	54.78 (18.19)	52.75 (14.89)	53.62 (15.98)
STAI-S score	36.07 (7.25)	39.57 (7.94)	37.76 (7.66)	41.22 (15.00)	36.92 (7.99)	38.76 (11.39)
Dot-probe						
Mean RT—threat	517 (65)	531 (40)	524 (54)	543 (61)	535 (56)	538 (57)
Mean RT—neutral	529 (66)	544 (45)	536 (56)	524 (48)	517 (54)	520 (50)
Threat bias score	11.54 (8)	13.13 (10)	12.31 (9)	−18.96 (16)	−17.22 (9)	−17.97 (12)
Affective spatial cuing						
Mean RT—threat valid	575 (100)	569 (69)	572 (85)	603 (80)	559 (70)	578 (76)
Mean RT—neutral valid	580 (105)	565 (69)	573 (88)	586 (79)	560 (74)	571 (75)
Mean RT—threat invalid	651 (129)	663 (90)	656 (110)	673 (103)	669 (111)	671 (105)
Mean RT—neutral invalid	671 (156)	656 (83)	664 (125)	682 (137)	674 (104)	677 (116)
Threat engagement	5.31 (23)	−4.47 (20)	0.59 (22)	−17.00 (14)	0.12 (24)	−7.22 (22)
Threat disengagement	−20.46 (43)	6.98 (44)	−7.22 (44)	−8.67 (70)	−4.85 (37)	−6.49 (52)
STRESS-RELATED MEASUREMENTS: STAI-S						
Pre-stressor	39.33 (7.91)	36.65 (8.26)	38.04 (8.05)	36.56 (13.55)	44.50 (12.27)	41.09 (13.13)
During-stressor	47.60 (9.72)	54.71 (9.93)	51.03 (10.30)	53.57 (9.12)	50.42 (11.07)	51.77 (10.16)
POST-TRAINING MEASUREMENTS						
LSAS Score	55.13 (17.89)	55.64 (23.19)	55.38 (20.24)	51.11 (15.77)	53.42 (19.76)	52.42 (17.77)
STAI-S score	33.60 (7.07)	36.07 (7.63)	34.79 (7.32)	36.23 (12.45)	41.42 (10.92)	39.20 (11.60)
Dot-probe						
Mean RT—threat	470 (46)	470 (27)	470 (37)	491 (38)	470 (51)	479 (46)
Mean RT—neutral	471 (39)	470 (25)	470 (32)	491 (40)	468 (42)	478 (42)
Threat bias score	1.14 (20)	−0.31 (18)	0.44 (18)	0.79 (14)	−1.75 (16)	−0.66 (15)
Affective spatial cuing						
Mean RT—threat valid	544 (58)	543 (49)	544 (53)	575 (107)	541 (67)	556 (86)
Mean RT—neutral valid	546 (65)	545 (50)	545 (57)	582 (92)	539 (70)	557 (81)
Mean RT—threat invalid	622 (92)	634 (80)	628 (85)	658 (129)	660 (91)	659 (106)
Mean RT—neutral invalid	618 (90)	633 (69)	625 (79)	663 (119)	664 (109)	664 (111)
Threat engagement	1.47 (22)	1.09 (23)	1.29 (22)	7.12 (24)	−2.33 (16)	1.72 (20)
Threat disengagement	4.41 (39)	1.48 (35)	2.99 (36)	−5.37 (32)	−3.51 (41)	−4.31 (36)

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Training approach-avoidance of smiling faces affects emotional vulnerability in socially anxious individuals

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Previous research revealed an automatic behavioral bias in high socially anxious individuals (HSAs): although their explicit evaluations of smiling faces are positive, they show automatic avoidance of these faces. This is reflected by faster pushing than pulling of smiling faces in an Approach-Avoidance Task (AAT; Heuer et al., 2007). The current study addressed the causal role of this avoidance bias for social anxiety. To this end, we used the AAT to train HSAs, either to approach smiling faces or to avoid them. We examined whether such an AAT training could change HSAs' automatic avoidance tendencies, and if yes, whether AAT effects would generalize to a new approach task with new facial stimuli, and to mood and anxiety in a social threat situation (a video-recorded self-presentation). We found that HSAs trained to approach smiling faces did indeed approach female faces faster after the training than HSAs trained to avoid smiling faces. Moreover, approach-faces training reduced emotional vulnerability: it led to more positive mood and lower anxiety after the self-presentation than avoid-faces training. These results suggest that automatic approach-avoidance tendencies have a causal role in social anxiety, and that they can be modified by a simple computerized training. This may open new avenues in the therapy of social phobia.

Keywords: social anxiety, AAT training, face turn AAT, approach-avoidance modification

Social anxiety disorder (SAD; American Psychiatric Association, 2000) is a common and debilitating disorder, associated with social and occupational impairment and considerable comorbidity with other psychiatric disorders (Stein and Kean, 2000). In the absence of effective treatment, SAD usually runs a chronic and disabling course (Dewit et al., 1999).

A large body of research on SAD attempted to identify factors playing a role in the etiology and maintenance of the disorder (e.g., Hirsch and Clark, 2004). One maintaining factor is the avoidance of threatening stimuli, for instance, social interactions (Wong and Moulds, 2011). According to Turk et al. (2001), avoidance prevents effective processing of the situation and disconfirmation of negative beliefs. Avoidance can be controlled and available to self-inspection, such as safety behaviors like wearing make-up to hide blushing (Wells et al., 1995), or it can be automatic, like keeping more distance from others (Rinck et al., 2010), or avoiding eye contact when looking at faces (Moukheiber et al., 2010). According to Voncken et al. (2011), such subtle avoidance behavior is especially relevant in the maintenance of SAD, as it might deteriorate the quality of interactions, which in turn may elicit more negative evaluations by others.

Since avoidance is partly automatic, indirect measures are needed for its assessment. A technique to assess implicit avoidance behavior is the Approach-Avoidance Task (AAT; Rinck and Becker, 2007). The AAT is based on the finding that pleasant stimuli elicit automatic approach tendencies, whereas unpleasant or threatening ones produce automatic avoidance tendencies (Chen and Bargh, 1999). Translating this into overt behavior (arm movements), approach is associated with pulling objects closer and avoidance with pushing them away (e.g., Rinck and Becker, 2007). In the AAT, participants see single pictures presented on a computer screen. On each trial, they move a joystick to make the picture disappear. When the joystick is pushed, the picture shrinks, when it is pulled, the picture grows in size. This correspondence of movement and visual feedback creates a strong impression of pulling the picture closer (approach) vs. pushing it away (avoidance). Typically, response times are correlated with picture valence: pleasant pictures are pulled closer more quickly, whereas unpleasant pictures are pushed away more quickly.

Heuer, Rinck and Becker (2007) used the AAT for studying approach-avoidance tendencies in social anxiety. They found automatic avoidance of smiling and angry faces in socially anxious participants (HSAs), reflected by shorter reaction times for pushing than for pulling. While the avoidance of angry faces may be considered adaptive and useful, automatic avoidance of positive social cues such as smiling faces is specific to HSAs. Notably, the bias was found although HSAs evaluated smiling faces positively in an explicit rating task. These findings of automatic avoidance of smiling faces in social anxiety were replicated by Lange et al. (2008) and Roelofs et al. (2010). According to Heuer et al. (2007), this implicit avoidance tendency might play a critical role in the maintenance of SAD, as it could interrupt adequate behavior in social interactions and increase anxiety caused by interactions.

However, the existing studies do not allow us to conclude that automatic approach-avoidance tendencies do indeed play a causal role in SAD. The observed avoidance of smiling faces might just as well be a symptom rather than a cause of SAD. In order to establish causal relations, an experimental manipulation of approach-avoidance tendencies is needed. Therefore, the current study attempted to train HSAs either to approach or to avoid smiling faces, using the same AAT that has earlier been used to measure smile-avoidance tendencies. Hence, the main questions of the current study were whether (1) such training would be effective in changing approach-avoidance tendencies in HSAs, and if so, (2) whether the effects would generalize to a new approach-avoidance situation with new faces, and (3) whether the training would affect subjective fear in a stressful social situation.

First, we expected that HSAs in the approach-smiling-faces training group would display a reduction in their tendency to avoid smiling faces after the training (i.e., be faster in pulling them closer). For HSAs in the avoid-smiling-faces training group, we expected that their tendency to avoid smiling faces would increase from pre- to post-assessment. Second, we hypothesized that the training effects would carry over to new faces in a new type of Approach-Avoidance Task, the Face-Turn AAT (FT-AAT; Voncken et al., 2011). Finally, we expected that HSAs in the approach-smiling-faces group would rate their mood more positively and would show less anxiety than HSAs in the avoid-smiling-faces group after giving a video-recorded self-presentation. Our expectations were based on previous findings showing that the modification of cognitive processes such as attention, associations, or approach-avoidance tendencies may have beneficial effects on disorders such as social phobia (Beard and Amir, 2008) or generalized anxiety disorder (Amir et al., 2009), or prevent relapse in treated alcoholics (Wiers et al., 2011; Eberl et al., 2013). Indeed, Taylor and Amir (2012) recently showed that a training to approach smiling and neutral faces did increase socially anxious participants' social approach behavior in a subsequent social interaction situation. However, in this study, no avoid-smiling faces condition was employed, and no effects of the training on state anxiety were found. Therefore, these results are encouraging, but they do not tell us whether approach-avoidance of positive social cues, i.e., smiling faces, has the postulated causal effects on anxiety in social situations.

METHODS

PARTICIPANTS AND DESIGN

Forty undergraduate students of Radboud University Nijmegen who scored high on a social anxiety pre-screening participated in this study in return for course credits. Of those, eight participants were excluded from further analyses because their scores on the Social Interaction Anxiety Scale (SIAS; Mattick and Clarke, 1998) were not elevated at the time of testing[1]. Participants were randomly assigned to one of two training conditions (approach-smiling-faces-and-avoid-checkerboards or vice versa), yielding 16 participants in each training group. The two groups did not differ on level of social anxiety or demographic variables (see **Table 1**). AAT reaction times (before and after the training), FT-AAT reaction times, and mood ratings before and after a social threat task were used as the dependent variables.

MATERIALS AND PROCEDURE

Questionnaires

Participants first gave informed consent, then filled out the fear sub-scale of the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987), the (SIAS; Mattick and Clarke, 1998), and the Zung Self-Rating Depression Scale (SDS; Zung, 1965). Those scoring high on the SDS would be excluded from further analyses, although this was not necessary as all participants scored at or below average.

Video rating

Subsequently, participants watched a 1-min video in which a woman, supposedly a previous participant, described herself (e.g., her hobbies, interests, etc.). Thereafter, participants were asked to rate this person according to 4 different aspects, namely: "How attractive/friendly/sympathetic/competent does this person seem?". This part was incorporated to make the final part of the experiment (see below) more plausible.

Mood ratings

After the video-rating, participants were asked to rate their mood by evaluating 3 negative statements ("How anxious/nervous/bored are you at the moment?") and 3 positive ones ("How happy/comfortable/relaxed are you at the moment?") on a 7-point scale (0= *not at all*, 6= *very much*). These mood ratings were repeated after each task during the experiment to assess changes in mood.

Table 1 | Means and standard deviations of demographics, questionnaire scores, AAT effects in ms, mood ratings, and anxiety ratings.

Training	Approach-Smile *n = 16*	Avoid-Smile *n = 16*
% Female	69%	81%
Age	20.7 (2.1)	20.8 (2.7)
LSAS-Fear	30.8 (11.1)	34.7 (8.6)
SIAS	37.1 (10.5)	37.3 (8.9)
SDS	40.6 (8.0)	38.5 (9.0)
AAT-pre	11 (105)	−63 (171)
AAT-post	120 (197)	−97 (156)
Mood rating 1 (Pre training)	5.3 (4.5)	6.5 (5.3)
Mood rating 2 (Post training)	2.9 (3.6)	5.0 (5.2)
Mood rating 3 (Post face-turn AAT)	4.0 (3.1)	5.8 (5.2)
Mood rating 4 (Pre self-presentation)	−0.56 (5.0)	1.6 (5.9)
Mood rating 5 (Post self-presentation)	4.9 (5.1)	2.3 (6.3)
Anxiety rating 1	1.1 (1.2)	1.3 (1.7)
Anxiety rating 2	0.69 (0.87)	0.81 (1.3)
Anxiety rating 3	0.44 (0.73)	0.94 (1.4)
Anxiety rating 4	2.3 (1.6)	2.3 (1.6)
Anxiety rating 5	1.1 (1.5)	2.3 (1.7)

[1]These 8 participants had SIAS scores lower than 21. Additional analyses including them yielded very similar results, except that the observed effects were smaller.

Pull-push AAT

Afterwards, the Pull-Push AAT followed. All participants were instructed to categorize pictures according to their *color* (gray vs. sepia) as quickly as possible, using a joystick. They always pulled the joystick toward themselves in response to gray pictures, and pushed it away in response to sepia pictures. The joystick (a Logitech Attack 3) was positioned about halfway between participant and computer, tightly fastened to the table. The stimuli were (a) smiling male and female faces derived from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998), and (b) neutral checkerboards. Each trial of the AAT was started by moving the joystick to the middle position and pressing the "fire button" of the joystick. Then a single picture was presented in medium size on the computer screen. A zoom function was employed, such that the picture grew in size when the joystick was pulled, and it shrank when it was pushed. The picture disappeared only when the joystick was moved completely into the correct direction. Response latencies were recorded automatically as the difference between time of picture appearance and disappearance.

Unbeknown to the participants, after 10 practice trials, the first part of the task was a pre-assessment phase (40 trials), in which they pulled and pushed both smiling faces and checkerboards (10 trials for each of the 4 combinations) to measure their pre-existing behavior tendencies. Without any obvious change or interruption, the pre-assessment phase changed into a training phase of 480 trials (240 faces, 240 checkerboards). For participants assigned to the *approach-smiling-faces group*, smiling faces were always gray-colored (approach), and checkerboards always sepia-colored (avoidance) in this phase. In the *avoid-smiling-faces group*, checkerboards were always gray (approach) and smiling faces always sepia (avoidance). After 440 training trials, and again without any obvious change in procedure, a post-assessment phase was inserted, which was identical to the pre-assessment phase. A comparison of the post-assessment to the pre-assessment was used to verify whether participants learned the intended approach-avoidance reactions. The task ended with the remaining 40 training trials. Subsequently, participants executed a dot-probe task[2] which lasted for approx. 10 min.

Face-Turn AAT

Afterwards, participants performed a Face-Turn Approach-Avoidance Task (FT-AAT), as described by Voncken et al. (2011), to measure whether the training effects generalized to a different approach-avoidance situation with new stimuli. Here, we used pictures of the faces of slightly friendly looking individuals (half male, half female) and pictures of computer monitors. In this task, joystick movements did not cause changes in picture size, but they made the depicted individuals or monitors turn toward the participant vs. away from him/her. At the beginning of each trial, the heads of the individuals would face to the left or to the right, and similarly, the front of the monitors would be directed to the left or to the right. Participants were instructed to push away all left-directed stimuli and to pull closer all right-directed ones. When pulling the joystick, faces (or monitors) turned around toward the participant in steps of 30 degrees, such that the frontal view of the face (or monitor) became apparent at the end (approach). Pushing away faces (or monitors) resulted in turning away from the participant with the back of the head (or monitor) as end point (avoidance). This task consisted of 12 practice trials and 96 experimental trials. The latter involved 16 pull trials and 16 push trials each for male faces, female faces, and monitors.

Social stress task

After this task, participants were asked to give a video-taped, one-minute self-presentation, comparable to the previously rated video. Participants video-recorded the presentation themselves, using a Logitech QuickCam. They were told that their video would be shown to the next participant, and that the next participant would evaluate the self-presentation in the way the current participant had just evaluated the previous participant. All participants agreed to this procedure, and no one doubted its validity. Nevertheless, to protect the participants' privacy, no video was actually presented to anybody else, and all videos were deleted after data collection was finished.

Participants also rated their mood both after the instructions (assessing fearful expectation) and after actually giving the self-presentation (assessing stress recovery). Comparisons of the two training groups at these two measurements served as our main dependent variable. Finally, participants gave some demographic information and completed an awareness check on paper. The overall experiment lasted about 50 min.

RESULTS

AAT: MANIPULATION CHECK

To test our first hypothesis that approach-avoidance tendencies could be trained, two new dependent variables were computed from the participants' median AAT reaction times (RTs), indicating their face-approach tendency relative to their checkerboard-approach tendency. One variable contained this information for the pre-assessment, and the other for the post-assessment. The mean values of these scores are shown in **Table 1**, positive values indicate a relative approach tendency for smiling faces, negative ones a relative avoidance tendency for them. As expected, the groups' approach-avoidance tendencies did not differ significantly from each other before training, $t_{(30)} = 1.48$, n.s. After the training, they did differ in the expected direction, $t_{(30)} = 3.45$, $p = 0.002$, with participants of the approach-faces training showing a significant face-approach tendency (+120 ms), $t_{(15)} = 2.43$, $p = 0.03$, and participants of the avoid-faces group showing a significant face-avoidance tendency (−97 ms), $t_{(15)} = 2.48$, $p = 0.03$. Thus, the Pull-Push AAT yielded the expected training effects.

FACE-TURN AAT

To test the hypothesis that AAT training effects generalize to a new AAT, a 2 (Training: approach-smiling-faces-avoid-checkerboards vs. vice versa) × 2 (Stimulus type: face, monitor) × 2 (Movement type: approach vs. avoidance) repeated-measures ANOVA was

[2]The dot-probe task was intended to measure effects of the approach-avoidance training on attention bias, but due to a design error, its results could not be interpreted. Therefore, it is not described in detail here. Information about it can be obtained from the first author.

conducted on the median Face-Turn AAT reaction times. This analysis did not reveal the expected three-way interaction, $F_{(1, 30)} < 1$, n.s. However, closer inspection of the means suggested a difference between male and female faces, therefore three exploratory 2 (Training: approach-smiling-faces-avoid-checkerboards vs. vice versa) × 2 (Movement type: approach vs. avoidance) repeated-measures ANOVAs were added, one for each picture type. The analysis for *female* faces yielded the expected two-way interaction between Movement type and Training, $F_{(1, 30)} = 8.16$, $p < 0.01$, $\eta_p^2 = 0.22$, but it was not found for male faces or monitors, both $F < 2$, *ns*. Further analyses of the female faces revealed that participants who had been trained to approach smiling faces did indeed approach female faces faster than participants who had been trained to avoid the faces, $t_{(30)} = 2.24$, $p = 0.04$ (see **Table 2** for means and standard deviations).

MOOD RATINGS

To test our hypothesis that the approach-smiling-faces group would rate their mood more positively, an overall mood score was created for each of the 5 mood-rating phases (M1–M5). This was done by subtracting the sum score of all negative mood items (anxious, nervous, bored) from the sum score of all positive mood items (happy, comfortable, relaxed). As such, a positive value of this overall mood score indicates a positive mood state, whereas a negative value indicates a negative mood state[3]. As we were particularly interested in the participants' mood directly before and after the self-presentation, only the corresponding M4 and M5 scores were entered into the analyses (however, all scores are reported in **Table 1**). As a first step, we conducted a repeated-measures ANCOVA on the overall mood scores, including the between-subjects factor Training (approach-smiling-faces-avoid-checkerboards vs. vice versa) and the within-subjects factor Time (M4 vs. M5). Mood scores at M1 were added as a covariate to control for pre-experimental mood differences. This analysis revealed the expected Training × Time interaction, $F_{(1, 29)} = 8.1$, $p < 0.01$, $\eta_p^2 = 0.22$. When investigating this interaction further, results of paired-samples *t*-tests demonstrated that for participants of the approach-faces training, mood after the self-presentation was significantly better than directly before, $t_{(15)} = 4.39$, $p < 0.01$. No significant difference was found for participants of the avoid-faces training, $t_{(15)} = 0.52$, *ns*.

In addition, we executed two ANCOVAs of the overall mood scores at M4 and M5 separately (again making use of mood scores at M1 as covariate). There was no significant mood difference between the two training groups at M4 before the social threat task, $F_{(1, 29)} = 0.73$, *ns*. Afterwards at M5, however, participants of the approach-faces training group reported a significantly more positive mood than those of the avoid-faces training group, $F_{(1, 29)} = 4.68$, $p = 0.04$, $\eta_p^2 = 0.14$. See **Table 1** for means and standard deviations of these scores.

ANXIETY RATINGS

Since the training was designed to specifically affect social anxiety, we also investigated its effects on the participants' anxiety. For this analysis, we used only one of the six mood ratings, namely the "How anxious are you at the moment?" rating. Again, we focused on the ratings directly before and after the self-presentation, computing the same analyses as above. The repeated-measures ANCOVA of the anxiety ratings yielded the expected Training x Time interaction, $F_{(1, 29)} = 7.52$, $p = 0.02$, $\eta_p^2 = 0.21$. Participants of the approach-faces training were less anxious after the self-presentation than before, $t_{(15)} = 4.84$, $p < 0.001$. In contrast, participants of the avoid-faces training reported a comparable level of anxiety before and after the self-presentation, $t_{(15)} = 0$, *ns*. Correspondingly, the two groups did not differ regarding their level of anxiety before the self-presentation, $F_{(1, 29)} = 0.03$, *ns*. Afterwards, the approach-faces group reported less anxiety than the avoid-faces group, $F_{(1, 29)} = 5.05$, $p = 0.04$, $\eta_p^2 = 0.15$. Please see means and standard deviations of these scores in **Table 1**.

DISCUSSION

The main goals of this study were to examine (a) whether a Pull-Push-AAT (Heuer et al., 2007) could serve as an appropriate method to influence automatic approach-avoidance tendencies in response to smiling faces, and if so, (b) whether the training effects would generalize to a new approach-avoidance situation with new faces, and (c) whether the training would affect subjective anxiety in a real social threat situation.

Our findings confirmed our first hypothesis that the AAT-training is suitable for changing HSAs' avoidance of smiling faces. Specifically, HSAs trained to approach smiling faces became faster in pulling smiling faces closer to themselves. After the training, they showed a significant face-approach tendency. Similarly, participants trained to avoid smiling faces showed a significant face-avoidance tendency. Hence, we can argue that the AAT is an appropriate and promising method to train HSAs to approach smiling faces. Moreover, it may have potential therapeutic value in the sense that it could help to reduce *automatic* avoidance behavior in social anxiety, in addition to the existing therapeutic tools for reducing *controlled* avoidance behavior.

Furthermore, our findings partially confirmed our second hypothesis as well. The trained action tendencies of the Pull-Push AAT seemed to generalize, to some extent, to new faces

[3] We also analyzed the sum score of the positive mood items and the sum score of the negative items separately. This yielded results which mirrored those of the joint analysis reported here.

Table 2 | Face-Turn-Approach-Avoidance Task: mean RTs and standard deviations in ms.

Training	Stimulus type	Movement type	
		Approach	Avoidance
Approach-smile	Female	703 (137)	749 (177)
	Male	734 (159)	702 (173)
	Monitor	711 (133)	684 (154)
Avoid-smile	Female	800 (106)	735 (127)
	Male	786 (139)	750 (125)
	Monitor	785 (148)	704 (93)

in a new type of AAT, the Face-Turn-AAT (Voncken et al., 2011). Here, HSAs trained to pull smiling faces closer were faster to turn female faces toward themselves. However, it must be noted that no effect on male faces was observed. An explanation for this finding could be that the female faces were perceived as less threatening by the predominantly female HSAs of the current experiment. Accordingly, future studies should determine if and how the training effects can be extended to male faces in order to increase the effectiveness of the training for treatment purposes. These studies should also pay attention to possible interactions of participant gender, model gender, and emotion because there is evidence that the processing of smiling facial expressions depends on the gender of both the person expressing them and the person perceiving them (LaFrance et al., 2003).

Finally, we expected that when experiencing a social challenge, HSAs who had received approach-smiling-faces training would feel generally better and would experience less anxiety than HSAs who received avoid-smiling-faces training. The reported mood ratings and anxiety ratings were in accordance with this hypothesis. Compared to HSAs of the avoid-faces training, HSAs of the approach-faces training reported both higher positive mood in general, and lower levels of anxiety in particular, after videotaping their self-presentation and expecting it to be evaluated by a peer. Interestingly, there were no differences between the two groups in general mood or specific anxiety when they received instructions for the self-presentation. This suggests that the training affected mood recovery after stress rather than anticipatory fear: HSAs who had been trained to approach smiling faces appeared to *recover* more easily after the social threat task. This result is in accordance with studies that tested the effects of another type of training, attention bias modification, on emotional vulnerability (MacLeod et al., 2002; Amir et al., 2008). As in our study, only participants' anxiety *after* the stressful event was affected by the training condition. Moreover, as in many previous studies (e.g., MacLeod et al., 2002), our training was not a selective mood induction: directly afterwards, both training groups felt slightly worse than before. This is understandable, given the somewhat boring nature of the training.

In the current study, we experimentally manipulated whether the participants were trained to approach or to avoid smiling faces. This way, we can safely conclude that automatic approach-avoidance tendencies are indeed causal factors in the behavior and subjective fear of socially anxious individuals. This is important from a theoretical point of view, e.g., for the evaluation of cognitive theories of anxiety. However, it does not yet prove the therapeutic value of an approach training in SAD because the positive approach-smiling faces training was not compared to a placebo training condition. In this respect, our study nicely complements the one recently reported by Taylor and Amir (2012) who found positive effects of an approach-faces training, compared to a placebo training condition. In this study, however, the authors only found effects of the training on social interaction behavior, not on subjective fear. For the latter, several differences between the two studies may be responsible. For instance, our social stress task may have been more threatening, or our training may have been more powerful because it involved the approach of smiling faces rather than neutral faces. Therefore, future studies should compare the approach-smiling faces training to a placebo training condition, preferably in diagnosed social phobics, and study effects on both behavior and social anxiety levels. Moreover, studies with delayed follow-up measurements would be helpful for determining the duration of approach-avoidance training effects.

Several limitations of the current study deserve mentioning. First, the sample was rather small, and it contained more female than male participants, therefore it was impossible to test the participant gender × model gender × emotion interaction mentioned above. Also, we had neither a non-anxious control group nor a group of SAD patients to compare the pre-training AAT scores to. Moreover, the study is lacking emotional expressions other than happy faces. Finally, the exact mechanisms by which the current training reaches its positive effects on stress recovery remain to be determined. We have reason to assume that more than a response bias was induced, given the observed partial transfer to another task and the effects on mood. At least two mechanisms might be at work here. First, operant evaluative conditioning: approaching certain stimuli repeatedly can make these stimuli more pleasant, compared to repeatedly avoiding them (e.g., Woud et al., 2011). This effect seems to be strongest for ambivalent stimuli, which smiling faces are for HSAs. Second, if the smiling faces were experienced as threatening, their repeated presentation might have caused habituation and extinction of the fear reaction, and this effect might have been stronger for those participants who approached the faces without experiencing any negative consequences.

To summarize, we have demonstrated that it is possible to change avoidance tendencies in HSAs using an AAT training procedure, and that the training effects partly generalize to other situations involving automatic approach behavior. Moreover, training HSAs to approach rather than to avoid smiling faces led to less self-reported anxiety after a threatening social task, thereby fostering recovery from stress. These results corroborate the causal role of automatic approach-avoidance tendencies in social anxiety. Moreover, the results suggests that the AAT is not only suitable for the assessment of biased avoidance behavior in social anxiety, but also for the re-training of this automatic behavior. Since avoidance behavior plays an important role in the maintenance of SAD, an effective training to approach smiling faces could be an important step toward the improvement of social interactions in socially anxious individuals. Thus, the approach-smiling-faces training could be a promising addition to more traditional treatments of social anxiety.

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REFERENCES

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorder Text Revision,* 4th Edn., Washington, DC: American Psychiatric Association.

Amir, N., Beard, C., Burns, M., and Bomyea, J. (2009). Attention modification program in individuals with generalized anxiety disorder. *J. Abnorm. Psychol.* 118, 28–33. doi: 10.1037/a0012589

Amir, N., Weber, G., Beard, C., Bomyea, J., and Taylor, C. T. (2008). The effect of a single session attention modification program on response to a public speaking challenge in socially anxious individuals. *J. Abnorm. Psychol.* 117, 860–868. doi: 10.1037/a0013445

Beard, C., and Amir, N. (2008). A multi-session interpretation modification program: changes in interpretation and social anxiety symptoms. *Behav. Res. Ther.* 46, 1135–1141. doi: 10.1016/j.brat.2008.05.012

Chen, M., and Bargh, J. A. (1999). Consequences of automatic evaluation: immediate behavioral predispositions to approach or avoid the stimulus. *Pers. Soc. Psychol. B.* 25, 215–224. doi: 10.1177/0146167299025002007

Dewit, D. J., Ogborne, A., Offord, D. R., and MacDonald, K. M. (1999). Antecedents of the risk of recovery from DSM-III-R social phobia. *Psychol. Med.* 29, 569–582. doi: 10.1017/S0033291799008399

Eberl, C., Wiers, R. W., Pawelczack, S., Rinck, M., Becker, E., and Lindenmeyer, J. (2013). Approach bias modification in alcohol dependence: do clinical effects replicate and for whom does it work best? *Dev. Cogn. Neurosci.* 4, 38–51. doi: 10.1016/j.dcn.2012.11.002

Heuer, K., Rinck, M., and Becker, E. S. (2007). Avoidance of emotional facial expressions in social anxiety: the approach-avoidance task. *Behav. Res. Ther.* 45, 2990–3001. doi: 10.1016/j.brat.2007.08.010

Hirsch, C. R., and Clark, D. M. (2004). Information-processing bias in social phobia. *Clin. Psychol. Rev*. 24, 799–825. doi: 10.1016/j.cpr.2004.07.005

LaFrance, M., Hecht, M. A., and Paluck, E. L. (2003). The contingent smile: a meta-analysis of sex differences in smiling. *Psychol. Bull.* 129, 305–334. doi: 10.1037/0033-2909.129.2.305

Lange, W.-G., Keijsers, G., Rinck, M., and Becker, E. (2008). Social anxiety and evaluation of social crowds: explicit and implicit measures. *Behav. Res. Ther.* 46, 932–943. doi: 10.1016/j.brat.2008.04.008

Liebowitz, M. R. (1987). Social phobia. *Mod. Probl. Pharmacopsychiatry* 22, 141–173.

Lundqvist, D., Flykt, A., and Öhman, A. (1998). *The Karolinska Directed Emotional Faces – KDEF*. Stockholm: Karolinska Institute.

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., and Holker, L. (2002). Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. *J. Abnorm. Psychol.* 111, 107–123. doi: 10.1037/0021-843X.111.1.107

Mattick, R. P., and Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav. Res. Ther.* 36, 455–470. doi: 10.1016/S0005-7967(97)10031-6

Moukheiber, A., Rautureau, G., Perez-Diaz, F., Soussignan, R., Dubal, S., Jouvent, R., and Pelissolo, A. (2010). Gaze avoidance in social phobia: objective measure and correlates. *Behav. Res. Ther.* 48, 147–151. doi: 10.1016/j.brat.2009.09.012

Rinck, M., and Becker, E. S. (2007). Approach and avoidance in fear of spiders. *J. Behav. Ther. Exp. Psy.* 38, 105–120. doi: 10.1016/j.jbtep.2006.10.001

Rinck, M., Rörtgen, T., Lange, W.-G., Dotsch, R., Wigboldus, D. H. J., and Becker, E. S. (2010). Social anxiety predicts avoidance behaviour in virtual encounters. *Cogn. Emot.* 24, 1269–1276. doi: 10.1080/02699930903309268

Roelofs, K., Putman, P., Schouten, S., Lange, W.-G., Volman, I., and Rinck, M. (2010). Gaze direction differentially affects avoidance tendencies to happy and angry faces in socially anxious individuals. *Behav. Res. Ther*. 48, 290–294. doi: 10.1016/j.brat.2009.11.008

Stein, M., and Kean, Y. (2000). Disability and quality of life in social phobia: epidemiologic findings. *Am. J. Psychiatry* 157, 1606–1613. doi: 10.1176/appi.ajp.157.10.1606

Taylor, C. T., and Amir, N. (2012). Modifying automatic approach action tendencies in individuals with elevated social anxiety symptoms. *Behav. Res. Ther.* 50, 529–536. doi: 10.1016/j.brat.2012.05.004

Turk, C. L., Lerner, J., Heimberg, R. G., and Rapee, R. M. (2001). "An integrated cognitive–behavioral model of social anxiety," in *From Social Anxiety to Social Phobia: Multiple Perspectives,* eds S. G. Hofmann, and P. M. DiBartolo (Needham Heights, MA: Allyn and Bacon), 281–303.

Voncken, M. J., Rinck, M., Deckers, A., and Lange, W.-G. (2011). Anticipation of social interaction changes implicit approach-avoidance behavior of socially anxious individuals. *Cognit. Ther. Res.* 36, 740–749. doi: 10.1016/S0005-7894(05)80088-7

Wells, A., Clark, D. M., Salkovskis, P., Ludgate, J., Hackmann, A., and Gelder, M. G. (1995). Social phobia: the role of in-situation safety behaviors in maintaining anxiety and negative beliefs. *Behav. Ther.* 26, 153–161. doi: 10.1177/0956797611400615

Wiers, R. W., Eberl, C., Rinck, M., Becker, E. S., and Lindenmeyer, J. (2011). Re-training automatic action tendencies changes alcoholic patients' approach bias for alcohol and improves treatment outcome. *Psychol. Sci*. 22, 490–497. doi: 10.1016/j.jbtep.2010.11.004

Wong, Q. J. J., and Moulds, M. L. (2011). The relationship between maladaptive self-beliefs characteristics of social anxiety and avoidance. *J. Behav. Ther. Exp. Psychiatry* 42, 171–178. doi: 10.1080/02699931.2011.628300

Woud, M. L., Becker, E. S., and Rinck, M. (2011). Induction of implicit evaluation biases by approach avoidance training: a commentary on Vandenbosch and De Houwer. *Cogn. Emot.* 25, 1331–1338.

Zung, W. (1965). A self-rating depression scale. *Arc. Gen. Psychiatry* 12, 63–70. doi: 10.1001/archpsyc.1965.01720310065008

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Looking on the bright side in social anxiety: the potential benefit of promoting positive mental imagery

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Current cognitive models of social phobia converge on the view that negative imagery is a key factor in the development and maintenance of the disorder. Research to date has predominantly focussed on the detrimental impact of negative imagery on cognitive bias and anxiety symptoms, while the potential benefit of promoting positive imagery has been relatively unexplored. Emerging evidence suggests however that positive imagery could have multiple benefits such as improving positive affect, self-esteem and positive interpretation bias, and enhancing social performance. The present article defends the view that combining bias induction with a repeated practice in generating positive imagery in a cognitive bias modification procedure could represent a promising area for future research and clinical innovation in social anxiety disorder.

Keywords: social anxiety, mental imagery, cognitive bias modification, treatment, combined cognitive bias

NEGATIVE IMAGERY IN SOCIAL ANXIETY

People with social anxiety disorder (SAD) frequently report experiencing negative self-imagery of how they think they appear to others in feared social situations (Hackmann et al., 2000). The assumption that this negative imagery may be important in maintaining social anxiety is a central tenet of most cognitive models of SAD (Clark and Wells, 1995; Rapee and Heimberg, 1997; Hofmann, 2007). For example, Clark and Wells (1995) model suggests that when socially anxious individuals enter a feared social situation, they shift their attention towards internal cues and use this information to infer how they appear to others. This internal information can often take the form of a distorted, negative self-image that individuals perceive as accurate.

Empirical support for the causal role of negative imagery in social anxiety has been established through a series of experimental studies (Hirsch et al., 2003, 2004; Stopa and Jenkins, 2007). Hirsch and colleagues conducted a series of experiments in which socially anxious participants were asked to hold an image in mind while taking part in two conversations with a stranger. During one conversation they were asked to hold in mind a negative image of the sort they would typically generate in anxiety provoking social situations, whereas during the other conversation they were instructed to hold a less negative (control) image in mind (based on a memory of a social situations in which they felt relaxed). Participants reported feeling more anxious when holding the negative image than the benign one. They also judged their social performance more negatively both in terms of showing more symptoms of anxiety and performing less well during the conversation.

Further support for the causal role of negative imagery in social anxiety has been provided in experimental studies conducted with low anxious participants. In Hirsch et al. (2005), participants who were normally confident public speakers were asked to generate a negative, positive or control (unrelated) self-image prior to giving a speech. Findings from socially anxious samples were replicated, with participants in the negative imagery condition reporting greater anxiety and judging their social performance as being poorer than those assigned to the positive imagery condition. A further line of inquiry explored how negative imagery influenced interpretation of ambiguous social situations. Examination of interpretative processes has particular relevance in social anxiety, as socially anxious individuals have been shown to exhibit a tendency to interpret ambiguous social events in a negative way (Clark and McManus, 2002). In Hirsch et al. (2003), participants were instructed to generate negative self-imagery while making "online" (i.e., as they read) interpretations of ambiguous social information. While participants assigned to a control (unrelated) task exhibited the usual non-threatening interpretation bias observed in non-anxious individuals (Hirsch and Mathews, 1997), those assigned to the negative self-imagery condition did not show such positive bias.

Interestingly, the link between imagery and bias was further shown to be reciprocal. In Hirsch et al. (2007), participants completed a repeated practice in accessing positive or negative interpretations of ambiguous social situations, a procedure known as "cognitive bias modification" (CBM; Mathews and Mackintosh, 2000). Following the completion of the CBM procedure participants were asked to imagine themselves in ambiguous social situations. Participants in the negative condition generated more negative self-imagery than those in the positive group, which demonstrated the reciprocal influence of bias on negative self-imagery. Additionally, when subsequently asked to imagine taking part in a stressful social situation, participants in the negative group rated their anticipated anxiety as being greater and their expected social performance as being poorer than those in the positive group. The bidirectional link shown between imagery and interpretation bias suggested the importance of examining the combined influence of cognitive biases in the maintenance of social phobia (Hirsch et al., 2006).

POSITIVE IMAGERY IN SOCIAL ANXIETY

In line with the general emphasis in clinical research on negative cognitions and affect, the programme of research outlined above mostly focussed on delineating the influence of induced negative self-imagery on negative interpretation bias, ratings of social performance and social anxiety. The converse possibility that inducing positive imagery might lead to opposite and thus beneficial effects on social anxiety has been largely unexplored. There is accumulating evidence, however, that socially anxious individuals exhibit a range of positivity impairments, including reduced positive affect, absence of positive interpretation bias and deficits in approach-oriented behavior (Alden and Taylor, 2004; Kashdan, 2007; Weeks and Heimberg, 2012). Thus, targeting these positive deficits may represent an important target for future treatment of SAD.

Positive self-imagery represents a promising candidate to intervene on these positivity impairments in social anxiety. Mental imagery has been demonstrated to elicit stronger emotions than other forms of processing (Holmes and Mathews, 2010; Pictet and Holmes, 2013). This evocative power has further been shown to apply to both positive and negative emotions, leading to the suggestion that mental imagery may act as an "emotional amplifier" (Holmes et al., 2008a). Mental images have further been found to produce stronger emotions when they are generated from a field perspective, rather than from the perspective of an observer. This finding holds relevance in SAD given the tendency among socially anxious individuals to generate negative self-imagery from an observer perspective (Wells and Papageorgiou, 1999). Other properties of mental imagery with relevance to social anxiety have been identified. For example, imagining an event happening in the future has been shown to increase the perceived likelihood that the same event will actually occur in the future (Carroll, 1978). Further, generating positive imagery of the future has been shown to enhance motivation and goal-oriented behavior (Libby et al., 2007; Pictet et al., 2011). Taken together, these results suggest that promoting positive, field perspective imagery of the future in SAD may lead to improvements in anxiety symptoms, cognitive biases and motivation to engage in social behaviors.

Only a few studies to date have directly examined the impact of positive mental imagery in the context of social anxiety. In Stopa and Jenkins (2007) as well as Vassilopoulos (2005), participants who held a positive image in mind while giving a speech reported feeling less anxious and performed better than those who held a negative image. A limitation of this finding was that in the absence of a control condition, it was impossible to tell whether the effects found reflected the influence of positive imagery, negative imagery or a combination of the two. More recently, Hulme et al. (2012) explored the effects of experimentally inducing positive imagery or negative imagery on self-esteem, both during the imagery induction task and after performing a social threat task in which participants experienced social exclusion. Both high and low socially anxious participants who had held a positive image in mind reported higher levels of self-esteem at both times of the experiment than those who had held a negative image. A limitation of these findings was that the effects found were short-lived as confined to a single experimental session. Stopa et al. (2012) addressed this by testing whether an extended imagery practice involving seven daily sessions of positive imagery could lead to beneficial effects in socially anxious individuals. The imagery induction method used in the study was based on Hirsch et al. (2003) and consisted of the following two stages. Participants were first asked to generate a positive (or negative) image based on a social situation in which they had felt relaxed (or anxious). They were then asked to practice holding the positive (or negative) image in mind while listening to descriptions of ambiguous social situations (e.g., being called to reception in a Doctor's surgery). Results indicated that after 1 week's practice, participants in the positive condition reported higher levels of self-esteem and better performance ratings during a conversation with a stooge (in both subjective and objective assessments of performance).

The preliminary findings about positive imagery are encouraging but a replication on a clinical population is warranted. A common limitation in the research described was the absence of a control condition, which made the findings confusingly imputable to either negative or positive imagery, or a combination of the two. Further, little is known to date about the optimal way to promote positive imagery in SAD. The method employed in previous studies to induce positive imagery involved asking participants to recall a memory in which they had felt relaxed, then inviting them to close their eyes and ask them a series of questions designed to prompt imagery, such as how they thought they looked and sounded, how they felt and how they came across to other people. Whilst this method has been successful in producing the expected changes in previous research, there are many other possible ways to promote positive imagery and more research is needed to identify they key aspects of imagery than need to be harnessed. A potential caveat with regards to the methodology used was the questions used to prompt imagery (i.e., how they thought they look and came across to other people) may have favored the generation of observer perspective imagery. Encouraging the use of field perspective imagery (i.e., seeing the event through one's own eyes) is likely to produce stronger effects on negative and positive emotions, and counteract the natural tendency among socially anxious individuals to imagine themselves from an observer perspective. A second caveat with regards to the methodology used is that it may be too challenging for individuals with clinical levels of social anxiety to recall and elaborate on a time when they had experienced a positive social situation. This possibility is supported by recent evidence showing that social anxiety is associated with an impairment in generating detailed imagery of past positive events (Moscovitch et al., 2011). One possible way to overcome this could be to train the generation of positive imagery in response to hypothetical, future-oriented scenarios rather than to past memories. Imagining the future involves similar psychological processes to remembering the past (Schacter et al., 2007), with the additional benefit that it may help reduce anticipatory anxiety and boost motivation to engage in future social activities.

POSITIVE IMAGERY AND COGNITIVE BIAS MODIFICATION (CBM) IN SOCIAL ANXIETY

The experimental research reviewed above evidenced a close and reciprocal relationship between imagery and negative interpretations of ambiguous social situations. In Hirsch et al. (2005), taking the perspective of a confident speaker rather than their own perspective was shown to block threatening inferences in people with high interview anxiety. However, it did not facilitate the generation of more benign interpretations. One possible explanation for this lack of effect on positive bias could be that participants may have struggled to adopt the perspective of a confident other as it was too far from what they would usually experience in similar situations. Another possible interpretation was that the induction procedure was too short-lived and thus not powerful enough to produce observable change in positive interpretation bias. By contrast, a more extensive practice of generating positive self-imagery in a CBM-I procedure could represent a more powerful way to produce changes in affect, cognition and behavior in a population of socially anxious individuals.

Only a few studies to date have explored the potential benefit of interpretation bias modification (CBM-I) for people with high levels of social anxiety (Murphy et al., 2007; Beard and Amir, 2008; Beard et al., 2011; Turner et al., 2011). Preliminary evidence supports the idea that CBM-I may be efficient at inducing a more benign (and less negative) interpretation bias and reducing anxiety symptoms in socially anxious individuals. However, very little is known about the durability of these effects as none of these studies included follow-up assessments. In the only attempt to combine CBM-I with mental imagery, Murphy et al. (2007) instructed high socially anxious participants to imagine themselves in a series of auditorily presented descriptions of social situations that started ambiguous but then were consistently resolved in a benign or negative way. Compared to a control condition where the same situations were presented but the outcome remained unspecified, participants who completed the benign interpretation training showed less negative and more positive interpretation biases, and further anticipated that they would be significantly less anxious in a future social situation. These effects were not imputable to group differences in state anxiety (as mood had been successfully equalized between the two groups following a filler task) and thus were directly due to the CBM-I procedure. Both the imagery and bias induction may have contributed to the positive effects found. At the time participants were presented with an upcoming social situation that could be potentially threatening (i.e., meeting two people they don't know for a 5 min conversation), those who had previously completed the positive interpretation training may have been influenced by their newly acquired bias and interpret the situation in a more benign way (congruently with the training). Alternatively, participants may have spontaneously generated a positive image of them taking part in the upcoming social situation and thus have anticipated less anxiety.

The present article defends the view that combining a repeated practice in generating positive imagery with a CBM-I intervention may be a helpful component in future treatment of SAD. A similar hypothesis has been suggested in the context of depression (Holmes et al., 2009). Depression and social phobia are highly comorbid disorders (Ohavon and Schatzberg, 2010) and share common positivity impairments, such as reduced positive affect, lack of positive interpretation bias and deficit in positive imagery (Rude et al., 2002; Holmes et al., 2008b; Werner-Seidler and Moulds, 2011).

The effects of imagery-focussed CBM on depression have been tested using analog and clinical samples of depressed participants (Blackwell and Holmes, 2010; Pictet et al., 2011; Lang et al., 2012). In imagery-focussed CBM, participants first completed an introductory session in which they were trained to use imagery in a specific way (i.e., vivid, from a field perspective) and then were given a practice session of the CBM tasks on the computer. Throughout the training, participants were repeatedly prompted to focus on imagining the scenarios with as much vividness as possible. Pictet et al. (2011) found that within an analog sample of dysphoric participants, those who had completed a positive imagery-focussed CBM exhibited greater improvements in positive mood and greater performance on a behavioral task assessing approach motivation and persistence than those who had completed a control imagery condition. In the first clinical test of imagery-focussed CBM, Blackwell and Holmes (2010) administered a multi-session program involving seven sessions of CBM to a small sample of participants with a current major depressive episode. Imagery-focussed CBM was found to lead to significant improvements in depressive symptoms and cognitive biases, and these improvements were maintained at 2 weeks follow-up. Although promising, the findings were limited by the absence of a comparison condition, which left open the possibility that "non-specific" factors as well as spontaneous recovery might have intervened.

Lang et al. (2012) addressed this limitation by exploring the impact of a multi session imagery-focussed CBM-I compared to a closely matched control version of the program in a sample of currently depressed patients. Participants in the positive condition showed significantly greater improvement in depressive symptoms and cognitive bias from pre- to post-treatment compared to those in the control condition, and these improvements were maintained at 2 weeks follow-up. Of relevance for a potential application of imagery-focussed CBM to people with social anxiety, participants assigned to the positive imagery condition in Lang et al. (2012) reported significant reductions in trait-anxiety. More recently, Williams et al. (2013) tested the effects of an online version of imagery-focussed CBM in which seven daily sessions of CBM were followed by a 10-week internet-based cognitive-behavioral therapy (iCBT). Results showed that compared to participants assigned to a waitlist control, those assigned to the imagery-focussed CBM-I showed significant reductions in depressive symptoms, anxiety and distress. In addition, about a third of the participants showed clinically significant change after imagery-focussed CBM-I, while the proportion of clinical response reached 65% when combined with iCBT.

CONCLUSION

SAD is a highly prevalent condition that causes considerable distress and significant functional impairments (Kessler et al., 2005). Effective psychological treatments exist but they are under-utilized due to the lack of qualified therapists and to the reluctance of some socially anxious people to disclose personal information to a stranger. This had led to increasing calls for the development of easily accessible and effective treatments (Clark et al., 2009). CBM procedures represent promising candidates as their format allows great flexibility and accessibility, and requires minimal clinical involvement. Early findings from clinical studies (Beard et al., 2011; Brosan et al., 2011; Amir and Taylor, 2012) suggest that CBM-I could be beneficial for socially anxious individuals, but more research is needed to determine the most efficient way to deliver CBM-I in clinical samples. Further, future research should include follow-up assessments to evaluate whether the effects of CBM are maintained over time. The research reviewed in this article converges on the proposition that using mental imagery could enhance the efficacy of CBM-I in SAD. One way in which we "resolve" the ambiguity of a social situation is by imagining the outcome. Hence, increasing access to positive and vivid representations of social situations in a CBM-I program could be a promising target for future treatments of SAD.

REFERENCES

Alden, L. E., and Taylor, C. T. (2004). Interpersonal processes in social phobia. *Clin. Psychol. Rev.* 24, 857–882. doi: 10.1016/j.cpr.2004.07.006

Amir, N., and Taylor, C. T. (2012). Interpretation training in individuals with generalized social anxiety disorder: a randomized controlled trial. *J. Consult. Clin. Psychol.* 80, 497–511. doi: 10.1037/a0026928

Beard, C., and Amir, N. (2008). A muti-session interpretation modification program: changes in interpretation and social anxiety symptoms. *Behav. Res. Ther.* 46, 1135–1141. doi: 10.1016/j.brat.2008.05.012

Beard, C., Weisberg, R. B., and Amir, N. (2011). Combined cognitive bias modification treatment for social anxiety disorder: a pilot trial. *Depress. Anxiety* 28, 981–988. doi: 10.1002/da.20873

Blackwell, S. E., and Holmes, E. A. (2010). Modifying interpretation and imagination in clinical depression: a single case series using cognitive bias modification. *Appl. Cogn. Psychol.* 24, 338–350. doi: 10.1002/acp.1680

Brosan, L., Hoppitt, L., Shelfer, L., Sillence, A., and Mackintosh, B. (2011). Cognitive bias modification for attention and interpretation reduces trait and state anxiety in anxious patients referred to an out-patient service: results from a pilot study. *J. Behav. Ther. Exp. Psychiatry* 42, 258–264. doi: 10.1016/j.jbtep.2010.12.006

Carroll, J. S. (1978). The effect of imagining an event on expectations for the event: an interpretation in terms of the availability heuristic. *J. Exp. Soc. Psychol.* 14, 88–96. doi: 10.1016/0022-1031(78)90062-8

Clark, D. M., Layard, R., Smithies, R., Richards, D. A., Suckling, R., and Wright, B. (2009). Improving access to psychological therapy: initial evaluation of the UK demonstration site. *Behav. Res. Ther.* 47, 910–920. doi: 10.1016/j.brat.2009.07.010

Clark, D. M., and McManus, F. (2002). Information processing in social phobia. *Biol. Psychiatry* 51, 92–100. doi: 10.1016/s0006-3223(01)01296-3

Clark, D. M., and Wells, A. (1995). "A cognitive model of social phobia," in *Social Phobia: Diagnosis, Assessment and Treatment*, eds R. G. Heimberg, M. R. Liebowitz, D. A. Hope and F. R. Schneier (New York: Guildford Press), 69–93.

Hackmann, A., Clark, D. M., and McManus, F. (2000). Recurrent images and early memories in social phobia. *Behav. Res. Ther.* 38, 601–610. doi: 10.1016/s0005-7967(99)00161-8

Hirsch, C. R., Clark, D. M., Williams, R., Morrison, J., and Mathews, A. (2005). Interview anxiety: taking the perspective of a confident other changes inferential processing. *Behav. Cogn. Psychother.* 33, 1–12. doi: 10.1017/s1352465804001729

Hirsch, C. R., and Mathews, A. (1997). Interpretative inferences when reading about emotional events. *Behav. Res. Ther.* 35, 1123–1132. doi: 10.1016/S0005-7967(97)80006-X

Hirsch, C. R., Mathews, A., and Clark, D. M. (2006). Imagery and interpretations in social phobia: support for the combined cognitive biases hypothesis. *Behav. Ther.* 37, 223–236. doi: 10.1016/j.beth.2006.02.001

Hirsch, C. R., Mathews, A., and Clark, D. M. (2007). Inducing an interpretation bias changes self-imagery: a preliminary investigation. *Behav. Res. Ther.* 45, 2173–2181. doi: 10.1016/j.brat.2006.11.001

Hirsch, C. R., Mathews, A., Clark, D. M., Williams, R., and Morrison, J. (2003). Negative self-imagery blocks inferences. *Behav. Res. Ther.* 41, 1383–1396. doi: 10.1016/s0005-7967(03)00057-3

Hirsch, C. R., Meynen, T., and Clark, D. M. (2004). Negative self-imagery in social anxiety contaminates social situations. *Memory* 12, 496–506. doi: 10.1080/09658210444000106

Hofmann, S. G. (2007). Cognitive factors that maintain social anxiety disorder. A comprehensive model and its treatment implications. *Cogn. Behav. Ther.* 36, 193–209. doi: 10.1080/16506070701421313

Holmes, E. A., Geddes, J. R., Colom, F., and Goodwin, G. M. (2008a). Mental imagery as an emotional amplifier: application to bipolar disorder. *Behav. Res. Ther.* 46, 1251–1258. doi: 10.1016/j.brat.2008.09.005

Holmes, E. A., Lang, T. J., and Deeprose, C. (2009). Mental imagery and emotion in treatment across disorders: using the example of depression. *Cogn. Behav. Ther.* 38, 21–28. doi: 10.1080/16506070902980729

Holmes, E. A., Lang, T. J., Moulds, M. L., and Steele, A. M. (2008b). Prospective and positive mental imagery deficits in dysphoria. *Behav. Res. Ther.* 46, 976–981. doi: 10.1016/j.brat.2008.04.009

Holmes, E. A., and Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clin. Psychol. Rev.* 30, 349–362. doi: 10.1016/j.cpr.2010.01.001

Hulme, N., Hirsch, C., and Stopa, L. (2012). Images of the self and self-esteem: do positive self-images improve self-esteem in social anxiety? *Cogn. Behav. Ther.* 41, 163–173. doi: 10.1080/16506073.2012.664557

Kashdan, T. B. (2007). Social anxiety spectrum and diminished positive experiences: theoretical synthesis and meta-analysis. *Clin. Psychol. Rev.* 27, 348–365. doi: 10.1016/j.cpr.2006.12.003

Kessler, R. C., Berglund, P., Demler, O., Merikangas, K. R., and Walters, E. E. (2005). Lifetime prevalence and ago-of-onset distributions of DSM-IV disorders in the National Comorbidity Survey Replication. *Arch. Gen. Psychiatry* 62, 593–602. doi: 10.1001/archpsyc.62.6.593

Lang, T. J., Blackwell, S. E., Harmer, C., Davison, P., and Holmes, E. A. (2012). Cognitive bias modification using mental imagery for depression: developing a novel computerized intervention to change negative thinking styles. *Eur. J. Pers.* 26, 145–157. doi: 10.1002/per.855

Libby, L. K., Shaeffer, E. M., Eibach, R. P., and Slemmer, J. A. (2007). Picture yourself at the polls-visual perspective in mental imagery affects self-perception and behavior. *Psychol. Sci.* 18, 199–203. doi: 10.1111/j.1467-9280.2007.01872.x

Mathews, A., and Mackintosh, B. (2000). Induced emotional interpretation bias and anxiety. *J. Abnorm. Psychol.* 109, 602–615. doi: 10.1037/0021-843x.109.4.602

Moscovitch, D. A., Gavric, D. L., Merrifield, C., Bielak, T., and Moscovitch, M. (2011). Retrieval properties of negative vs. positive mental images and autobiographical memories in social anxiety: outcomes with a new measure. *Behav. Res. Ther.* 49, 505–517. doi: 10.1016/j.brat.2011.05.009

Murphy, R., Hirsch, C. R., Mathews, A., Smith, K., and Clark, D. M. (2007). Facilitating a benign interpretation bias in a high socially anxious population. *Behav. Res. Ther.* 45, 1517–1529. doi: 10.1016/j.brat.2007.01.007

Ohavon, M., and Schatzberg, A. (2010). Social phobia and depression: prevalence and comorbidity. *J. Psychosom. Res.* 68, 235–243. doi: 10.1016/j.jpsychores.2009.07.018

Pictet, A., and Holmes, E. A. (2013). "The powerful impact of mental imagery in changing emotion," in *Changing Emotions*, eds B. Rimé, B. Mesquita and D. Hermans (London: Psychology Press), 187–194.

Pictet, A., Coughtrey, A. E., Mathews, A., and Holmes, E. A. (2011). Fishing for happiness: the effects of positive imagery on interpretation bias and a behavioral task. *Behav. Res. Ther.* 49, 885–891. doi: 10.1016/j.brat.2011.10.003

Rapee, R. M., and Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behav. Res. Ther.* 35, 741–756. doi: 10.1016/s0005-7967(97)00022-3

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., and Whitney, T. (2002). Negative processing biases predict subsequent depressive symptoms. *Cogn. Emot.* 16, 423–440. doi: 10.1080/02699930143000554

Schacter, D. L., Addis, D. R., and Buckner, R. L. (2007). Remembering the past to imagine the future: the prospective brain. *Nat. Rev. Neurosci.* 8, 657–661. doi: 10.1038/nrn2213

Stopa, L., Brown, M. A., and Hirsch, C. (2012). The effects of repeated imagery practice on self-concept, anxiety and performance in socially anxious participants. *J. Exp. Psychopathol.* 3, 223–242. doi: 10.5127/jep.021511

Stopa, L., and Jenkins, A. (2007). Images of the self in social anxiety: effects on the retrieval of autobiographical memories. *J. Behav. Ther. Exp. Psychiatry* 38, 459–473. doi: 10.1016/j.jbtep.2007.08.006

Turner, R., Hoppitt, L., Hodgekin, J., Mackintosh, B., and Fowler, D. (2011). Cognitive bias modification in the treatment of social anxiety in early psychosis: a single case series. *Behav. Cogn. Psychother.* 39, 341–347. doi: 10.1017/s1352465810000706

Vassilopoulos, S. (2005). Social anxiety and the effects of engaging in mental imagery. *Cognit. Ther. Res.* 29, 261–277. doi: 10.1007/s10608-005-2993-4

Weeks, J. W., and Heimberg, R. G. (2012). Editorial-special issue positivity impairments: pervasive and impairing (yet nonprominent?) features of social anxiety disorder. *Cogn. Behav. Ther.* 41, 79–82. doi: 10.1080/16506073.2012.680782

Wells, A., and Papageorgiou, C. (1999). The observer perspective: biased imagery in social phobia, agoraphobia and blood injury phobia. *Behav. Res. Ther.* 37, 653–658. doi: 10.1016/s0005-7967(98)00150-8

Werner-Seidler, A., and Moulds, M. L. (2011). Autobiographical memory characteristics in depression vulnerability: formerly depressed individuals recall less vivid positive memories. *Cogn. Emot.* 25, 1087–1103. doi: 10.1080/02699931.2010.531007

Williams, A. D., Blackwell, S. E., Mackenzie, A., Holmes, E. A., and Andrews, G. (2013). Combining imagination and reason in the treatment of depression: a randomized controlled trial of internet-based cognitive bias modification and internet-CBT for depression *J. Consult. Clin. Psychol.* 81, 793–799. doi: 10.1037/a0033247

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