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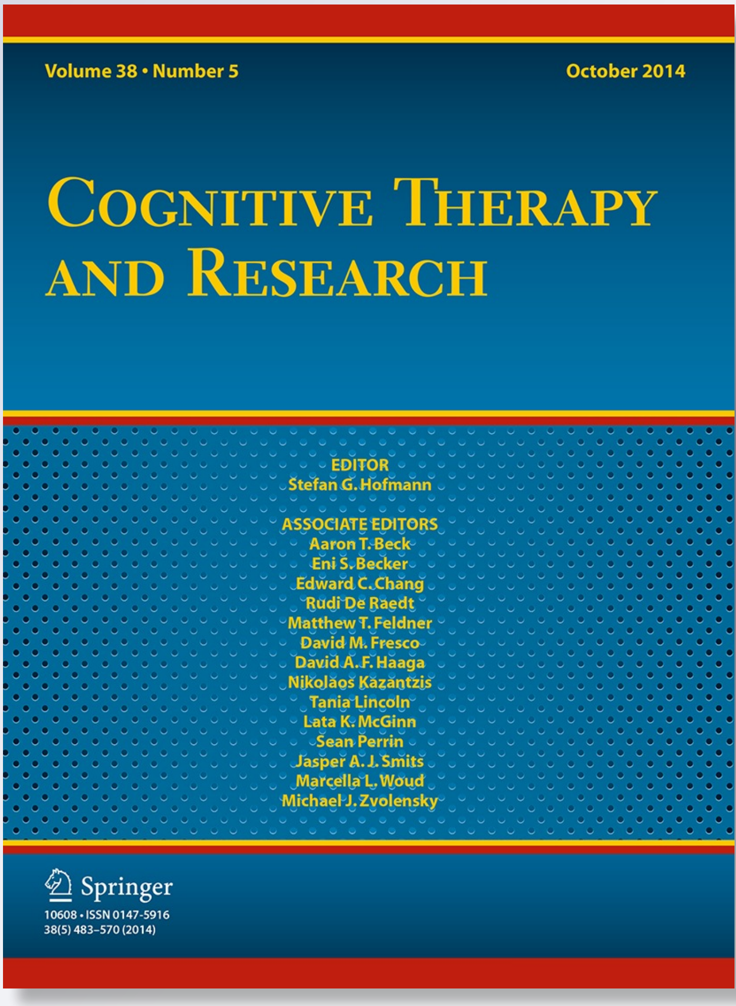

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BRIEF REPORT

Perceptual Sensitivity and Response Bias in Social Anxiety: An Application of Signal Detection Theory

K. Lira Yoon · Jae-Won Yang · Sang Chul Chong · Kyung Ja Oh

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Abstract Social anxiety is associated with tendencies to perceive other people's facial expressions in a negative manner. Two independent factors, sensitivity to and response criteria for emotional faces, may contribute to this bias. By applying signal detection theory and employing morphed facial stimuli with equated levels of intensity, we examined sensitivity to and response criteria for faces that were subtly angry or happy with a sample of 88 college students. Higher levels of social anxiety were associated with both greater sensitivity to mild anger and tendencies to label facial expressions as angry. In contrast, levels of social anxiety were not significantly associated with either sensitivity to or response criteria for mildly happy faces. These results indicate that the processing of negative facial expressions in social anxiety is affected by both greater sensitivity to the detection of threats and a bias for judging ambiguous social cues as threatening.

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Keywords Social anxiety · Facial expressions · Sensitivity · Bias · Signal detection theory

Introduction

The ability to identify and interpret facial expressions is crucial to understanding the intents, thoughts, and emotions of one's interacting partner(s). Evaluations of others are frequently inferred from facial expressions. As such, the processing of facial expressions is especially pertinent to understanding social anxiety, which is characterized by fear of being evaluated negatively by others (APA 2000). Cognitive models of social anxiety (e.g., Clark and Wells 1995; Hirsch and Clark 2004) suggest that socially anxious individuals manifest negative biases in social information processing. For example, it has been postulated that such individuals interpret neutral or ambiguous facial expressions in a negative manner (e.g., Yoon and Zinbarg 2008). Although some studies failed to support this notion (e.g., Philippot and Douilliez 2005), other studies have reported that socially anxious individuals interpret neutral faces as threatening (e.g., Mohlman et al. 2007; Yoon and Zinbarg 2007, 2008). Even when there were no significant group differences in the accuracy of classifying facial expressions, socially anxious individuals were more likely than healthy controls to classify neutral facial expressions as angry (Bell et al. 2011).

Overall, previous research has demonstrated that social anxiety is associated with tendencies to perceive other people's facial expressions in a negative manner. However, the mechanisms underlying this bias remain largely unknown. Biases in processing ambiguous facial expressions could stem from two independent sources: (a) individual differences in the response criterion (i.e., bias) and

(b) individual differences in sensitivity. The present study was designed to investigate the roles of these two factors in socially anxious individuals' processing of facial expressions by applying signal detection theory (SDT; Green and Swets 1966). SDT allows us to distinguish between individuals' ability to detect a given affective expression, such as angry (i.e., sensitivity: d'), and their tendency to label a face of any given expression as a particular expression—as angry or happy in the current study (i.e., bias or the response criterion: c). By applying SDT, the current study can determine whether socially anxious individuals are better at detecting a threat (e.g., anger) in others' facial expressions (i.e., high sensitivity to anger), or whether they are simply more likely to report that all facial expressions look threatening regardless of the actual expression (i.e., a lower response criterion for anger). Similarly, are such individuals poor at detecting a happy expression (i.e., lower sensitivity to happiness), or are they simply less likely to report it (i.e., a higher response criterion for happiness)?

To the best of our knowledge, only two studies have applied SDT to investigate the processing of facial expressions in social anxiety. In one study (Winton et al. 1995), participants were presented with facial pictures and asked to indicate whether each facial expression was negative. Socially anxious individuals exhibited a more liberal response criterion than their counterparts but did not differ in their sensitivity. Similarly, Veljaca and Rapee (1998) reported that socially anxious individuals adopted a more liberal criterion for reporting negative (vs. positive) behaviors of an audience while giving a speech. Unlike Winton et al., Veljaca and Rapee demonstrated that socially anxious individuals were, in fact, more sensitive to negative behaviors (e.g., yawning) than to positive behaviors (e.g., nodding), whereas less anxious participants were more sensitive to positive behaviors.

Given the sparsity of SDT studies and their inconsistent findings, additional research is needed to clarify the roles of sensitivity and response criteria in socially anxious individuals' processing of facial expressions. Furthermore, previous studies used strong exemplars of positive and negative feedback (Veljaca and Rapee 1998) or images of full-blown facial expressions (Winton et al. 1995). In everyday social situations, however, individuals are more likely to encounter much less intense cues than the stimuli used in previous studies. A recent study used morphed facial stimuli to examine bias and sensitivity in emotion detection (Frenkel et al. 2009). Considering that this study examined the perception of emotional stimuli in trait anxiety, there is still a need for studies directly assessing facial expression processing in social anxiety. Furthermore, Frenkel et al. used fearful faces. Although fear is also a negative emotion, fear and anger raise quite different implications. A fearful face may (e.g., the person in the picture is fearful of the observer) or may not (e.g., if the fear is elicited by a third person/object) be a threatening stimulus for the observer. In contrast, angry faces can more universally convey a threat. Therefore, we used angry faces instead of fearful faces in the current study.

In this study, we presented ambiguous facial expressions, each created by blending neutral (i.e., no expression) faces and full-blown expressions of anger or happiness. We used a morphed picture set with established thresholds for detecting a particular emotion along each expression continuum, ranging from neutral to full-blown (Yang and Oh 2009). This ensured that the intensity of the emotion expressed in each image (i.e., the intensity of the emotion in a happy vs. angry face) was equal.

On the basis of cognitive models of social phobia (e.g., Clark and Wells 1995), we hypothesized that the level of social anxiety would be associated with greater sensitivity to anger and a more liberal response criterion. We also examined the processing of happy faces due to the mounting evidence that non-anxious individuals exhibit a positive bias that is absent in socially anxious individuals (e.g., Hirsch and Mathews 2000; Yang et al. 2013). We hypothesized that higher levels of social anxiety would be associated with lower sensitivity to detect happiness and a more conservative response criterion for judging happy faces.

Methods

Participants

Eighty-nine Korean undergraduate psychology students participated in this study in exchange for course credit. They had normal or corrected-to-normal vision. One participant misunderstood the study procedure and was excluded from all analyses. Thus, the final analyses were based on 88 participants (57 women and 31 men; mean age = 22.37).

Measure

Participants completed the Social Interaction Anxiety Scale (SIAS; Mattick and Clarke 1998), which assesses one's level of social anxiety. Participants indicated the degree to which each statement described themselves on a 5-point Likert scale ranging from 0 (*not at all true of me*) to 4 (*extremely true of me*). The Korean version of the SIAS has demonstrated good reliability (Cronbach's $\alpha = .92$; Kim 2001), with a clinical sample in Korea exhibiting comparable SIAS scores ($M = 51.75$, $SD = 9.98$; Chung and Kwon 2006) to those reported in Peters (2000; $M = 55.24$, $SD = 12.97$). In the current study, Cronbach's

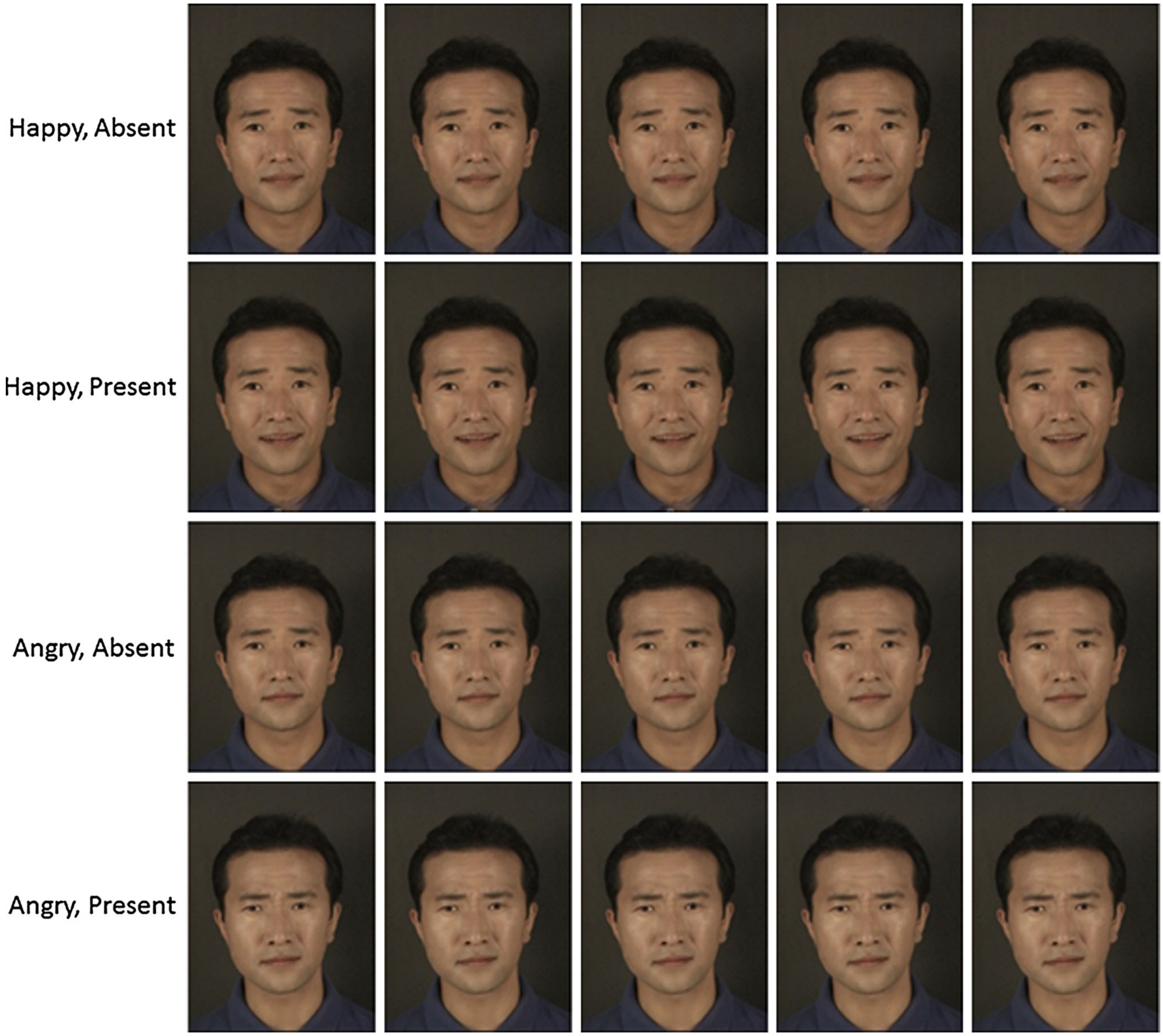

Fig. 1 Examples of the morphed facial pictures used in the current study

α was .88, and the mean SIAS score was 22.24 (*SD* = 10.20).

Stimuli

We used images of four models (two women and two men) that were also used in Yang and Oh (2009). Yang and Oh morphed a neutral face and an emotional face (either angry or happy) selected from a well-validated Korean face database (Face Database of Yonsei University Center for Cognitive Science 1998) in 50 steps to create finely graded continua of expressions ranging from neutral (no expression) to full-blown anger or happiness. These authors presented morphed faces successively, either from neutral to emotional (i.e., in ascending order) or from emotional to neutral (i.e., in descending order). The participants' task was to detect when a specific emotion emerged (the ascending order condition) or when a specific emotion disappeared (the descending order condition). Using the method of limits (Gescheider 1976), Yang and Oh identified participants' emotion detection thresholds for each continuum. In the current study, for each model and facial expression, the five consecutive images immediately below the threshold of the descending order condition in Yang and Oh (2009) were used as neutral faces (i.e., emotion absent = non-target images). Likewise, the five consecutive images immediately above the threshold of the ascending order condition were selected as emotional faces (i.e., emotion present = target images). Examples of target and non-target images are presented in Fig. 1. Typically, it would be unclear whether the intensity of, for instance, a 30 % happy face (i.e., a 70:30 neutral:happy blend) is identical to the intensity of a 30 % angry face. Just because two morphed pictures were created with the same blend ratio does not necessarily ensure that the two faces are equal in terms of the intensity of emotion. In the current study, however, we can rule out the possibility that the intensities are dissimilar, as we selected stimuli with known thresholds. A total of 80 pictures were used for the main trials. A total of 20 pictures (10 pictures each for happy and angry faces) were selected from another well-validated Korean face database for use in practice trials (Lee et al. 2006).

Task

The participants' task was to determine whether a specific emotion was present or absent in each image. All pictures within a block were of the same type. At the beginning of each block, participants were informed of the type of emotion (i.e., angry or happy) that they had to judge as being present or absent in each picture. Each trial started with a 500 ms fixation point, followed by a $12.08° \times 16.06°$ image. After 40 ms, the facial picture was masked for 40 ms by a phase-scrambled version of the presented face (Ganis and Kutas 2003). Next, a fixation point appeared, at which point participants were asked to indicate whether the image depicted a particular emotion (per the instruction at the beginning of each block) by pressing the appropriate response key. In each block, participants first completed 20 practice trials before proceeding to the main trials. As stated earlier, the pictures used in the practice trials were different from those used in the main trials. In each block (i.e., happy and angry), participants completed 80 main trials (i.e., 40 target images and 40 non-target images), with each picture being presented twice. In total, there were 40 practice trials and 160 main trials. The order of the blocks was counterbalanced between participants. The task was written using MATLAB (Mathworks, MA) in conjunction with the Psychophysics Toolbox (Brainard 1997; Pelli 1997).

Procedure

Participants provided written informed consent, after which they completed the SIAS (Mattick and Clarke 1998). Next, they were introduced to the main task. Participants were seated in front of a 17″ CRT-computer monitor with a refresh rate of 75 Hz. They completed a total of 200 trials followed by a debriefing. All procedures were approved by the local Institutional Review Board.

Data analysis

Based on the number of correct responses (i.e., responding "yes" when a specific emotion was actually present) and incorrect responses (i.e., responding "yes" to a non-target image), we computed hit rates (*H*) and false alarms (*FA*) separately for angry and happy faces. The sensitivity index, d', indicates the degree to which a participant was able to discriminate a true signal (i.e., target faces that depict specific emotions) from noise (i.e., neutral, non-target faces). The formula for d' is as follows (MacMillan 1993):

$$d' = \Phi^{-1}(H) - \Phi^{-1}(F)$$

The Φ function, which is one-tailed, determines the portion of the normal distribution that lies to the left of the z score, causing larger z scores to yield higher probabilities. The Φ^{-1} (inverse phi) function converts probabilities into z scores. For example, Φ^{-1} (.05) = −1.64, which means that a one-tailed probability of .05 requires a z score of −1.64. Thus, d' is computed by subtracting the z score that corresponds to the false alarm rate from the z score that corresponds to the hit rate. When d' equals zero, a participant is completely unable to discriminate between the two. As d' increases, sensitivity also increases.

The formula for c is as follows (MacMillan 1993):

$$c = -\frac{\Phi^{-1}(H) + \Phi^{-1}(F)}{2}$$

The response criterion, c, represents the willingness of the person to respond "yes," indicating that a specific emotion is present. When c equals zero, there is no response bias. Positive c scores suggest that a person is biased towards responding that a specific emotion is absent, whereas negative c scores suggest that a person is biased towards responding that a specific emotion is present (Stanislaw and Todorov 1999).

None of the participants had 100 % *FA*. However, there were participants with 100 % hits. For these participants, we used (n − 0.5)/n, where n is the number of the signal trials (MacMillan and Kaplan 1985; Stanislaw and Todorov 1999). For participants whose *FA* was 0, rates of 0 were replaced with 0.5/n, where n is the number of the noise trials (MacMillan and Kaplan 1985; Stanislaw and Todorov 1999).

Results

Overall Performance

Before examining the association between social anxiety and the processing of facial expressions (i.e., sensitivity and response criteria), we examined differences in these

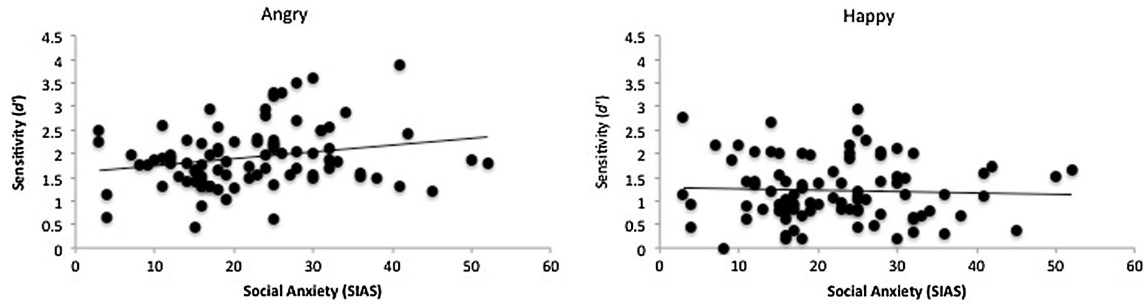

Fig. 2 Sensitivity (d') for angry (*left panel*) and happy (*right panel*) facial expressions

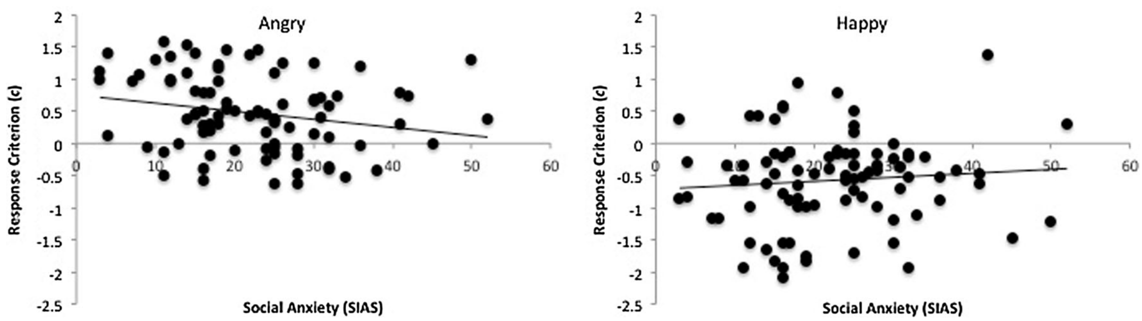

Fig. 3 Response criteria (c) for angry (*left panel*) and happy (*right panel*) facial expressions

indices between angry and happy expressions. To this end, we conducted two separate paired-samples t tests. Sensitivity to angry expressions (M = 1.93, SD = 0.66) was significantly higher than sensitivity to happy expressions (M = 1.22, SD = 0.65), $t(87) = 8.40$, $p < .001$. In contrast, the response criterion for happy expressions (M = −0.57, SD = 0.71) was significantly lower than that for angry expressions (M = 0.47, SD = 0.59), $t(87) = -10.15$, $p < .001$. Thus, participants were more sensitive to anger-related features, whereas they adopted a more liberal criterion for reporting happy expressions. Response criteria for both happy expressions, $t(87) = -7.59$, $p < .001$, and angry expressions, $t(87) = 7.52$, $p < .001$, were significantly different from zero. Thus, participants were biased towards reporting that anger was absent and towards reporting that happiness was present.

Social Anxiety and Emotion Recognition

The main aim of this study was to examine the contribution of sensitivity and response criteria (i.e., response bias) to the processing of facial expressions in social anxiety. To this end, we conducted two Emotion × Social Anxiety General Linear Models (GLMs), which allow the continuous nature of social anxiety to be preserved, thereby increasing power. For sensitivity, there was a significant emotion by social anxiety interaction, $F(1,86) = 4.59$, $p = .035$, $\eta_p^2 = .05$. No other effects were significant. This interaction was due to the fact that the main effect of social anxiety was significant for angry faces, $F(1,86) = 4.51$, $p = .037$, $\eta_p^2 = .05$, but not for happy faces, $F(1,86) < 1$, *ns*. Not surprisingly, levels of social anxiety were significantly associated with sensitivity to angry faces, $r = .22$, $p = .037$. In contrast, levels of social anxiety were not significantly associated with sensitivity to happy faces, $r = -.05$, *ns*. Thus, higher levels of social anxiety were associated with greater sensitivity to perceive anger in others (Fig. 2). That is, participants with higher levels of social anxiety were better at discriminating angry from neutral expressions.

For the response criterion, the main effect of emotion was significant, $F(1,86) = 35.86$, $p < .001$, $\eta_p^2 = .29$, and the interaction between emotion and social anxiety approached significance, $F(1,86) = 3.55$, $p = .063$, $\eta_p^2 = .04$. Similar to sensitivity, the main effect of social anxiety was significant for angry faces, $F(1,86) = 4.33$, $p = .04$, $\eta_p^2 = .05$, but not for happy faces, $F(1,86) < 1$, *ns*. Again, levels of social anxiety were significantly associated with the response criterion for angry faces, $r = -.22$, $p = .04$, but not for happy faces, $r = .09$, *ns*. The participants in general exhibited a more liberal criterion for reporting happy (vs. angry) expressions, which was more evident in less anxious individuals (Fig. 3). That is, lower levels of social anxiety were associated with a tendency to adopt a more stringent criterion for angry expressions.

Discussion

The current study sheds light on the mechanisms underlying the previously reported bias in socially anxious individuals' processing of ambiguous facial expressions. Our results indicate that two independent factors contribute to the manner in which such individuals process social cues. Higher levels of social anxiety are associated with more accurate detection of actual threat cues (i.e., better sensitivity to angry expressions) and a more liberal criterion (i.e., response bias) for perceiving a facial expression as angry. Thus, socially anxious individuals may process others' facial expressions in a negative manner (e.g., Yoon and Zinbarg 2007, 2008) because they have a negative response bias and are genuinely better at detecting negative emotions in other people.

In the current study, participants in general were more sensitive to threat cues than to positive cues in the facial pictures. Evolutionarily speaking, missing threat cues that are actually present can be more costly than missing positive cues. Therefore, it is possible that human beings are generally more tuned to detect negative as opposed to positive cues. At the same time, the participants exhibited a tendency to label ambiguous expressions as happy (i.e., a response bias towards labeling happy faces). The well-documented presence of positivity bias under normal circumstances (Cacioppo et al. 1997) may be responsible for the overall liberal response criterion for happy faces. Given that happy facial expressions convey fondness and provide interpersonal security (Frenkel et al. 2009), any bias towards judging ambiguous social cues in a positive manner could be self-protective and adaptive (Johnson and Fowler 2011).

The findings that social anxiety is associated with higher sensitivity to angry cues and a liberal bias towards perceiving anger are consistent with previous findings (Veljaca and Rapee 1998). However, unlike the current findings and those by Veljaca and Rapee, sensitivity to negative facial expressions did not differ between groups in the study by Winton et al. (1995). Considering that Winton et al. used prototypical, full-blown facial expressions, there may have been a ceiling effect that obscured any social anxiety-related differences in sensitivity to anger. The employment of more subtle forms of social cues may have led to greater variability in sensitivity in the current study, allowing individual differences in sensitivity to emerge.

Two independent sources can contribute to higher sensitivity to threat cues in individuals with high levels of social anxiety. First, socially anxious individuals may have an enhanced ability to detect threat cues (e.g., they require less inspection time to abstract affective information from other people's facial expressions) (Veljaca and Rapee 1998). Second, socially anxious individuals' tendency to attend selectively to threat cues (see Heinrichs and Hofmann 2001, for a review) may lead to better detection of socially threatening cues. The paradigm of the present study allows participants' attentional resources to be fully allocated to each stimulus (i.e., no competing distracters). Therefore, at least with respect to the current findings, differences in the actual ability to detect threat cues seem to better account for the higher sensitivity associated with social anxiety. However, socially anxious individuals' greater vigilance towards threats (Mogg and Bradley 2002) could still play a role in their higher sensitivity to threat cues. That is, in the real world where there are multiple competing stimuli, socially anxious individuals' tendency to attend to threat cues could help them avoid missing any threat signals.

The current findings suggest a potential intervention target for socially anxious individuals' tendency to interpret facial expressions in a negative manner (e.g., Yoon and Zinbarg 2008): An intervention could help them adopt a more stringent criterion. In this regard, interpretation bias training paradigms in which socially anxious individuals are trained to adopt more benign interpretations (e.g., Murphy et al. 2007) might shift socially anxious individuals' response criterion for threat information.

The current study is not without limitations. The findings were obtained using non-clinical participants whose mean SIAS score was well below the level expected in a clinical population. However, considering that non-clinical individuals with high levels of social anxiety are similar to individuals diagnosed with social anxiety disorder (Turner et al. 1986), similar findings would be expected with clinical samples. Nevertheless, individuals diagnosed with social anxiety disorder may demonstrate different patterns (e.g., exhibit lower sensitivity to happy expressions). For this reason, generalizing the current findings to a clinical population should be cautioned.

It may be tempting to argue, based on cognitive theories of social anxiety (e.g., Clark and Wells 1995), that the higher sensitivity to and lower response criterion for anger found in this study represent risk factors for social anxiety. However, the current study cannot speak to causal relationships due to its correlational design. Moreover, we cannot eliminate the possibility of a third variable (e.g., state anxiety; Westermann and Lincoln 2010) that may be associated with both social anxiety and the detection of angry faces. Attentional biases to threat could be a potential third variable, and examining perceptual sensitivity and attentional biases in the same sample could clarify the role of attentional biases in sensitivity to threat cues. In addition, investigating sensitivity to and response criteria for other relevant expressions (e.g., disgust) and the effects of stress on these indices could enhance our understanding of social anxiety.

Despite these limitations, the current study has unique strengths. By employing morphed faces, we were able to examine perceptions of ambiguous facial expressions of the sort frequently encountered in the real world. More importantly, the stimuli used in the current study are equal in terms of the strength of the depicted facial expressions. The fact that we employed a stimulus set with known thresholds to detect emotion provides confidence in our conclusion that levels of social anxiety are associated with sensitivity to and response criteria for perceiving anger. More specifically, social anxiety is associated with both greater sensitivity to threat cues and a bias towards judging ambiguous social cues as threatening. Such a pattern may lead socially anxious individuals to perceive their interactions as more threatening than they are in reality, possibly exacerbating their anxiety.

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Conflict of Interest K. Lira Yoon, Jae-Won Yang, Sang Chul Chong and Kyung Ja Oh declare that they have no conflict of interest.

Informed Consent Informed consent was obtained from all participants before inclusion in the study.

Animal Rights No animal studies were carried out by the authors for this article.

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