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Abstract

Physiological activation is thought to be a part of the constellation of responses that accompany social anxiety, but evidence regarding the nature of such activation is mixed. In two studies, the relationship between trait social anxiety and responses during social interaction was explored using on-line cardiovascular indexes of threat. Across Studies 1 and 2, women higher in trait social anxiety exhibited cardiovascular responses consistent with greater threat during the social interaction than those lower in social anxiety. Retrospective self-reports (Studies 1 and 2), as well as partner ratings and interaction behavior (Study 2), also revealed consistent differences as a function of trait social anxiety. Study 2 added male participants, among whom a divergence emerged between results for physiological measures and other responses. These findings have implications for understanding physiological as well as psychological processes among people with social anxiety during social interaction.

Keywords

trait social anxiety, social interaction, challenge and threat, cardiovascular reactivity, psychophysiology

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Social anxiety disorder, or social phobia (American Psychiatric Association, 2000), is a fairly common disorder in the United States, with a lifetime prevalence of 13.3%, making it the third most frequently occurring psychological disorder (Kessler et al., 1994). Even when full diagnostic criteria for social phobia are not met, social anxiety manifests as a personality trait with important implications. Social anxiety is described as a cognitive-affective syndrome in which excessive and persistent apprehension and sympathetic nervous system activation occur in anticipation of or during social interaction (e.g., Leary & Kowalski, 1995; Westenberg, 1998). Highly socially anxious participants retrospectively report experiencing more negative affect following a social interaction than their less socially anxious counterparts as well as more negative self-related thoughts (see Bruch, 2001, for a review). On the other hand, evidence regarding the relationship between social anxiety and physiological responses is mixed. In the current studies, we sought to clarify the characterization of trait social anxiety by further testing its physiological component during social interaction.

Heart rate (HR) and blood pressure (BP)—sensitive in part to sympathetic activation (Brownley, Hurwitz, & Schneiderman, 2000)—have been commonly assessed in the investigation of social anxiety. For example, Gramer and Saria (2007) found higher HR and BP responses during a

speech task among participants high in social anxiety compared to those low in social anxiety (also see Hofmann, Newman, Ehlers, & Roth, 1995; Houtman & Bakker, 1991; Levin et al., 1993). However, in a study of older adults performing a speech task, Grossman, Wilhelm, Kawachi, and Sparrow (2001) found that social phobia interacted with gender: Socially phobic women exhibited exaggerated HR and BP (as well as cardiac output and systemic vascular resistance) relative to nonphobic women, but no differences emerged among men. Others have failed to observe any HR and BP differences as a function of social anxiety or phobia (Anderson & Hope, 2009; Miller & Arkowitz, 1977; Puigcerver, Martinez-Selva, Garcia-Sanchez, & Gomez-Amor, 1989).

Beyond HR and BP, accumulated evidence suggests that there are few, if any, reliable differences in physiological

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responses during social interaction between people high versus low in social anxiety. Edelman and Baker (2002) found no differences in skin conductance level (SCL), facial and neck temperature, and HR during four different tasks, including social conversation. Furthermore, Mauss, Wilhelm, and Gross (2003) found no differences between high versus low trait socially anxious people in various physiological responses, such as HR, BP, SCL, finger pulse amplitude, respiratory rate, and respiratory sinus arrhythmia, during a speech task, habituation, or recovery period (also see Mauss, Wilhelm, & Gross, 2004). Importantly, based on this lack of physiological differences for social anxiety, some researchers argue that cognitive processes (e.g., attentional focus, negative self-schemata) rather than physiological processes play a crucial role in developing and maintaining social anxiety (Grossman et al., 2001; Mauss et al., 2003). In other words, although people with social anxiety often *report* some physiological reactions during social interactions, these reports may reflect response biases rather than actual physiological changes (similar to what occurs for some other anxiety disorders; Roth et al., 1992; Roth, Wilhelm, & Trabert, 1998).

Such conflicting evidence for physiological responses associated with social anxiety may be at least partly the result of the particular measures that were assessed in much of the previous work. Rather than leading to widespread activation across the sympathetic nervous system (i.e., undifferentiated arousal), it is possible that social anxiety instead predicts more specific and nuanced changes. Consistent with this idea, the biopsychosocial model of challenge and threat (BPS; Blascovich, 2008; Blascovich & Tomaka, 1996) suggests a pattern of cardiovascular responses that should more closely reflect the psychological states experienced by the socially anxious during actual social interaction.

BPS

The BPS (Blascovich, 2008; Blascovich & Tomaka, 1996) provides a theoretical physiological basis for cardiovascular indexes of psychological states experienced during motivated performance situations. Motivated performance situations are those in which individuals must actively work to achieve valued goals. Examples include test taking, game playing, and—relevant for the current investigation—social interaction, during which individuals desire to make a good impression and/or avoid negative evaluation. According to the BPS, in the context of a motivated performance situation, *task engagement* occurs to the extent that the task goal is subjectively self-relevant to the individual. Thus, at least as long as task outcomes are not certainties (e.g., an impossible task), more valued or important goals lead to higher task engagement (Seery, Weisbuch, & Blascovich, 2009). Given task engagement, relative *challenge* occurs when evaluated personal resources are relatively high and situational demands are low, whereas relative *threat* occurs when demands are

relatively high and resources are low. Although labeled as discrete states, challenge and threat represent opposite ends of a single bipolar continuum, such that relative differences in challenge and threat (e.g., greater vs. lesser challenge) are meaningful (for a thorough review, see Blascovich, 2008).

The cardiovascular responses associated with challenge/threat do not equate to challenge/threat itself but instead represent an indirect measure of the underlying psychological state. We used four cardiovascular measures to index challenge/threat: HR; ventricular contractility (VC), an index of the left ventricle's contractile force; cardiac output (CO), the amount of blood pumped by the heart (L/min); and total peripheral resistance (TPR), an index of net constriction versus dilation in the arterial system. In the context of a motivated performance situation, increases in HR and VC from baseline reflect task engagement and are common across the challenge/threat continuum. Given this reactivity, relative threat is marked by lower CO and higher TPR than relative challenge.

These cardiovascular responses have been empirically validated as markers of challenge/threat (for a review, see Blascovich, 2008) and have been employed successfully in several dozen studies examining various psychological processes, including religious belief systems (Weisbuch-Remington, Mendes, Seery, & Blascovich, 2005), stereotype threat (Vick, Seery, Blascovich, & Weisbuch, 2008), self-esteem (Seery, Blascovich, Weisbuch, & Vick, 2004), and defensive pessimism (Seery, West, Weisbuch, & Blascovich, 2008), as well as prospectively predicting athletic and academic performance (Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Seery, Weisbuch, Hetenyi, & Blascovich, 2010). The theoretical underpinnings for these cardiovascular changes derive from Dienstbier's (1989) model of psychophysiological toughness, specifically, differential activation of the sympathetic-adrenomedullary (SAM) and pituitary-adrenocortical (HPA or PAC) axes. Both challenge and threat are hypothesized to result in heightened SAM activation, yielding increases in HR and VC. During challenge, SAM activation is thought to lead to relatively high CO and low TPR. Because threat is believed to also result in heightened HPA activation, which may inhibit the epinephrine-mediated vasodilation that would otherwise occur, relatively low CO and high TPR result (Blascovich, 2008; cf. Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003; Wright & Kirby, 2003).

Social Anxiety and Challenge/Threat

The BPS thus suggests that social anxiety should predict specific cardiovascular patterns during social interaction. Consistent with apprehension and fear of an upcoming social interaction and negative affect and self-related thoughts after an interaction (Bruch, 2001; Leary, 2001; Leary & Kowalski, 1995; Westenberg, 1998), higher social anxiety should lead to evaluations of lower resources and higher demands

during social interaction than lower social anxiety. This should in turn lead participants high in social anxiety to exhibit the threat cardiovascular pattern, relative to participants low in social anxiety.

In addition to our primary predictions for challenge/threat, we also examined cardiovascular measures of task engagement. To the extent that social anxiety is partially a function of heightened concern with gaining approval and avoiding disapproval from a real or imagined social interactant (e.g., Leary, 2001; Schlenker & Leary, 1982), people higher in social anxiety may evaluate greater goal relevance—and thus be more engaged—during a social interaction than people lower in social anxiety. Although previous research has yielded inconsistent results for HR, VC—the BPS's other measure of task engagement—has not to our knowledge been reported in the context of social anxiety.

Study 1

In Study 1, female participants were asked to interact with a confederate in a private laboratory room after completing questionnaires including a social anxiety scale. We examined participants' cardiovascular responses during the interaction. After the interaction, participants were asked to report their retrospective anxiety during the interaction. We hypothesized that, compared to participants low in social anxiety, participants high in social anxiety would be more likely to report negative affect and exhibit relative threat during the interaction.

Method

Participants. Participants were 90 female undergraduates enrolled in introductory psychology courses.¹ They received partial course credit for their participation.

Trait social anxiety. The Interaction Anxiousness Scale (IAS) was used to measure chronic tendencies toward social anxiety during interaction (Leary & Kowalski, 1993). The IAS primarily measures affective aspects of social anxiety. Namely, this self-report questionnaire consists of 15 items that refer to subjective feelings of either anxiety or calmness during social interactions. Responses range from 1 (*not at all characteristic of me*) to 5 (*extremely characteristic of me*). Sample items include "I often feel nervous even in casual get-togethers" and "I seldom feel anxious in social situations." In the current sample (as in previous investigations), this scale was highly reliable ($\alpha = .90$; $M = 37.35$, $SD = 10.00$). Trait social anxiety was treated as a continuous variable. We standardized the scale total ($M = 0$, $SD = 1$) to facilitate interpretation of analyses (see below).

Postinteraction self-report measures. Following the social interaction, participants were asked to indicate, on a 5-point scale ranging from -2 (*strongly disagree*) to 2 (*strongly agree*), the extent to which they agreed with statements

about their feelings during the social interaction. Participants were asked to retrospectively rate the extent to which they felt anxious, content, enthusiastic, confident, sad, nervous, and uneasy. The four negatively valenced items were reverse scored, and all seven were averaged into a single affect scale ($\alpha = .87$), in which higher values reflected more positive affect. Because people with social anxiety are often concerned with approval from a real or imagined social interactant (e.g., Leary, 2001; Schlenker & Leary, 1982), an additional item assessed the extent to which participants were concerned about what their interaction partner thought of them. A final item asked how much participants liked their interaction partner.

Cardiovascular measures. Cardiovascular measures were recorded noninvasively, following accepted guidelines (Sherwood et al., 1990) and utilizing a Minnesota Impedance Cardiograph (Model 304B) and a Cortronic (Model 7000) continuously inflated BP monitor. Signals were conditioned using Coulbourn amplifiers and were stored on a desktop computer. Impedance cardiograph (ICG) and electrocardiograph (ECG) recordings provided continuous measures of cardiac performance. The ICG utilized a tetrapolar aluminum/mylar tape electrode system to record basal transthoracic impedance (Z_0) and the first derivative of impedance change (dZ/dt), sampled at 1 kHz. ECG signals were detected using either a Standard Lead II electrode configuration (additional spot electrodes on the right arm and both legs) or through the band electrodes. The Cortronic BP monitor collected continuous noninvasive recordings of BP from the brachial artery of participants' nondominant arm. In combination, ICG and ECG recordings allowed computation of HR, VC (for presentational purposes, pre-ejection period reactivity $\times -1$), and CO; the addition of BP monitoring allowed computation of TPR (mean arterial pressure $\times 80/\text{CO}$; Sherwood et al., 1990). The recorded data were ensemble averaged in 60 s intervals and scored using an interactive MS-DOS software program (Kelsey & Guethlein, 1990). Scoring was performed blind to other participant data.

Procedure. Participants completed the experiment individually. Upon arrival at the laboratory, an experimenter escorted participants to a recording room. Here, participants were left alone to complete a consent form and the IAS. Afterward, the experimenter reentered the room and applied sensors necessary for cardiovascular recording. Participants sat upright in a comfortable upholstered chair. Before leaving the recording room, the experimenter instructed participants to sit quietly and relax for several minutes.

A 5-min rest period began when the experimenter left the room, during which baseline levels of cardiovascular responses were assessed. At the conclusion of the rest period, participants heard audio instructions over an intercom, informing them that a member of the research team would now enter the chamber to engage in a "getting to know you" exercise. After instructions were played, a female interviewer,

Table 1. Correlations and Descriptive Statistics in Study 1

Measure	1	2	3	4	5	6	7	8	9
1. Challenge/threat index	—								
2. TPR	-.96***	—							
3. CO	.96***	-.84***	—						
4. HR	-.16	.21*	-.08	—					
5. VC	-.15	-.11	.17	.26*	—				
6. Social anxiety	-.21*	.17	-.24*	.01	-.03	—			
7. Retrospective positive affect	.17	-.11	.21*	.11	.14	-.66***	—		
8. Concern for partner's impression	-.18	.12	-.22*	.03	-.07	.48***	-.53***	—	
9. Liking for partner	.05	-.06	.04	.15	-.03	-.28**	.49***	-.07	—
<i>M</i>	0	46.29	-0.43	8.94	2.10	37.35	3.56	2.62	3.88
<i>SD</i>	1	106.98	0.88	6.19	6.10	10.00	0.70	1.15	0.70

Note: TPR = total peripheral resistance; CO = cardiac output; HR = heart rate; VC = ventricular contractility. Cardiovascular values reflect the mean of reactivity scores from all task minutes.

* $p < .05$. ** $p < .01$. *** $p < .001$.

unfamiliar to participants, entered the recording room. The interviewer introduced herself and sat down to start a conversation. The conversation lasted 3 min, during which cardiovascular measurements were recorded. In this interaction, the interviewer asked participants a predetermined set of questions about themselves such as “Tell me about your hometown” and “What are your plans after college?” This format encouraged participants to actively engage in conversation. After the interviewer left the recording room, participants completed the retrospective measure of affect and the other self-report measures. Upon completion, the experimenter removed cardiovascular sensors and participants were thoroughly debriefed.

Results

Postinteraction self-report measures. We first conducted a correlation analysis to see if trait social anxiety was associated with retrospective self-reported affect. In replication of prior research (cf. Bruch, 2001), this analysis revealed a significant correlation, $r = -.66$, $p < .001$, such that participants higher in social anxiety reported more negative affect during the social interaction than those lower in social anxiety. Also replicating prior research (e.g., Leary, 2001; Schlenker & Leary, 1982), higher social anxiety was associated with having greater concern about what their interaction partner thought of them, $r = .48$, $p < .001$, and less liking for their partner, $r = -.28$, $p < .01$. See Table 1 for a correlation matrix and descriptive statistics.

Analytic strategy for cardiovascular responses. As is standard in challenge/threat research (e.g., Seery et al., 2004), we analyzed cardiovascular reactivity values (task value minus baseline value; see Llabre, Spitzer, Saab, Ironson, & Schneiderman, 1991, for psychometric justification for the use of change scores in psychophysiology). Univariate outliers (values more than 3.3 standard deviation units from the

grand mean; Tabachnick & Fidell, 1996) were Winsorized by changing the deviant raw score to a value 1% larger or smaller than the next most extreme score.

Because changes in CO and TPR—which reveal reactivity consistent with relative differences in challenge/threat—should reflect the same underlying SAM versus HPA activation, we combined CO and TPR (across 3 task minutes, $r_s = -.81$ to $-.83$, $p_s < .001$) into a single index by converting participants' CO and TPR reactivity values for each task minute into z scores, summing them, and standardizing the total ($M = 0$, $SD = 1$; see Blascovich et al., 2004; Seery et al., 2009; Seery et al., 2010). We assigned CO a weight of +1 and TPR a weight of -1 (i.e., TPR was reverse scored), such that a smaller value corresponded to reactivity consistent with greater threat. Using this index allowed us to maximize reliability of the cardiovascular measures and simplify analyses by conducting one test of challenge/threat reactivity. Reactivity was calculated by subtracting the last baseline minute value from each of the 3 task minute values.

To account for any effects of baseline cardiovascular levels on reactivity values, we controlled for baseline in challenge/threat analyses using an index calculated in the same fashion as for reactivity. We further controlled for a similar index of HR/VC task reactivity in which both HR and VC were weighted positively; because increases in HR and VC reflect SAM activation (thought to be a component of both challenge and threat), controlling for the reactivity of these measures should increase power to distinguish challenge from threat (see Seery et al., 2004; Vick et al., 2008).

To test challenge/threat responses over the entire social interaction, we conducted repeated-measures analyses across all task minutes with generalized estimating equations (GEE; see Zeger & Liang, 1992), which provides necessary adjustments of standard errors and yields a single significance test for each predictor across all time points. Appropriate for our

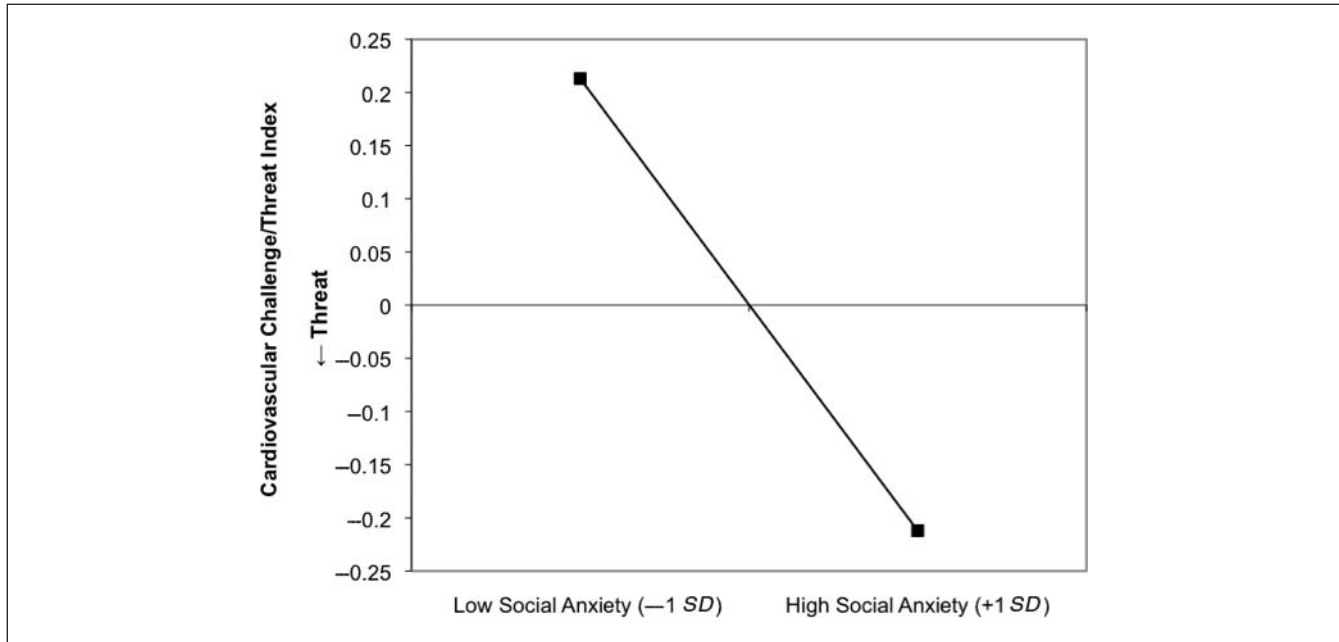


Figure 1. Challenge/threat reactivity during the social interaction task as a function of social anxiety (Interaction Anxiousness Scale)
 Note: A lower index value indicates greater relative threat.

research question, GEE focuses on between-subject effects (i.e., differences between respondents with different levels of social anxiety) rather than within-subject effects (i.e., trajectories within individuals over time). Coefficients from GEE models thus have analogous meaning to coefficients from standard multiple regression. Analyses were conducted with Stata (Version 9.2), specifying an unstructured correlational structure between task minutes (i.e., each pairwise correlation between minutes is free to differ) and—unless otherwise noted—including a continuous variable representing task time. Time did not significantly interact with social anxiety, so predicted values representing the midpoint of the task are presented. Because GEE utilizes maximum likelihood estimation, traditional measures of effect size based on accounting for variance cannot be calculated. To make results more interpretable, trait social anxiety was standardized ($M = 0$, $SD = 1$) so that model coefficients reflect effect sizes in units of standard deviations.

Task engagement. Given that increases in HR and VC are necessary components of the reactivity pattern for both challenge and threat, we first tested if predicted HR and VC reactivity across all task minutes was greater than zero for the sample as a whole (i.e., in an intercept-only model). Both HR and VC increased significantly from baseline during the task, $B = 9.61$, $z = 14.91$, $p < .001$, and $B = 2.21$, $z = 3.56$, $p < .001$, respectively, thereby justifying further investigation of challenge/threat differences. However, trait social anxiety did not predict engagement. Separately predicting HR and VC reactivity with trait social anxiety yielded no effects that approached significance, $z_s < 0.47$, $p_s > .63$.

Challenge/threat. Trait social anxiety was not significantly associated with the challenge/threat index during baseline, $r = .05$, $p = .65$, suggesting that cardiovascular responses did not differ as a function of social anxiety before the actual social interaction. In contrast and as expected, trait social anxiety significantly predicted challenge/threat responses during the social interaction, $B = -0.21$, $z = -2.12$, $p < .05$. As depicted in Figure 1, participants higher in social anxiety exhibited cardiovascular responses consistent with greater threat. See Table 2 for descriptive statistics regarding cardiovascular measures at baseline and at each task minute.

Discussion

As in previous research, individuals higher in social anxiety retrospectively reported higher negative affect after a social interaction as well as greater concern about what their interaction partner thought of them and less liking for their interaction partner. Our primary focus was to assess cardiovascular responses as a function of social anxiety *during* social interaction, which has yielded inconsistent results in previous research. Applying the BPS model of challenge/threat (Blascovich, 2008; Blascovich & Tomaka, 1996) to this question suggested a psychologically meaningful pattern of cardiovascular responses that should be related to social anxiety. Specifically, participants higher in social anxiety exhibited cardiovascular responses consistent with greater threat (i.e., higher TPR, lower CO) during the social interaction than participants lower in social anxiety. This is in line with the idea that higher social anxiety should lead to evaluations of

Table 2. Means and Standard Deviations for Cardiovascular Values During Baseline and Reactivity During Each Task Minute in Study 1

Measure	Baseline		1st task min		2nd task min		3rd task min	
	M	SD	M	SD	M	SD	M	SD
TPR	794.88	258.43	46.57	108.40	51.14	141.75	45.24	105.70
CO	8.92	2.22	-0.38	0.93	-0.43	1.00	-0.49	0.93
HR	76.03	12.44	12.03	7.08	7.58	6.61	7.22	6.39
VC	97.31	11.87	3.36	6.62	1.66	6.17	1.27	6.77

Note: TPR = total peripheral resistance; CO = cardiac output; HR = heart rate; VC = ventricular contractility.

lower resources and higher demands than lower social anxiety. We also tested for differences in cardiovascular markers of task engagement (HR and VC) as a function of social anxiety, but in line with prior research demonstrating inconsistent effects for HR, no significant effects emerged.

Study 2

The purpose of Study 2 was to replicate Study 1 and increase its generalizability in four ways. First, we included both male and female participants. Second, we used a different measure of social anxiety that focuses on not only affective aspects but also behavioral aspects of social anxiety. Third, in addition to a retrospective self-report measure of affect, we assessed participants' behavior during the interaction and their interaction partners' impression of them. Finally, we lengthened the interaction (from 3 to 5 min) and changed how the interaction partner was presented. Although participants in Study 1 believed that they were interacting with a member of the research team, participants in Study 2 were led to believe that they were interacting with another participant, thus making the interaction seem more like a conversation and less like an interview.

Because people with social anxiety typically engage in social interaction passively rather than actively (Clark & Wells, 1995; Cuming et al., 2009), we hypothesized that participants high in social anxiety would be less likely to ask questions, be more likely to answer questions, and speak for a shorter amount of time than those low in social anxiety. As in Study 1, we predicted that higher social anxiety would be associated with higher retrospectively reported negative affect. For challenge/threat, we expected to replicate Study 1's results for female participants, such that higher social anxiety would predict cardiovascular responses consistent with greater threat, perhaps especially among women (cf. Grossman et al., 2001).

Method

Participants. Participants were 184 undergraduates (102 men) enrolled in introductory psychology courses. They received partial course credit for their participation.

Trait social anxiety. The Liebowitz Social Anxiety Scale (LSAS) was used to measure chronic tendencies toward social anxiety during interaction (Heimberg et al., 1999). Unlike the IAS, the LSAS assesses not only affective aspects of social anxiety (i.e., how anxious people feel in social situations) but also behavioral aspects (i.e., the extent to which people avoid the situations). Although the LSAS was originally developed as a clinician-rating scale, the self-report version of the LSAS has been demonstrated to be a valid measure of social anxiety (Fresco et al., 2001). This measure was designed to assess the range of social interaction and performance situations that people with social anxiety may fear and/or avoid. Specifically, the measure consists of 24 items that address social interaction situations such as talking to people in authority and going to a party (11 items) and performance situations such as telephoning in public and participating in small groups (13 items). Participants were asked to read each situation and answer two questions about that situation: how anxious or fearful they would feel in the situation using a 4-point scale (0 = *none*, 3 = *severe*) and how often they avoid the situation using a 4-point scale (0 = *never* [0%], 3 = *usually* [67%–100%]). Because both subscales showed adequate reliabilities ($\alpha = .89$ and $.90$, respectively) and because those two subscales were highly correlated ($r = .94$), we averaged scores on the subscales to create a single index of social anxiety ($\alpha = .97$; $M = 3.89$, $SD = 0.92$). Trait social anxiety was treated as a continuous variable. We standardized the scale total ($M = 0$, $SD = 1$) to facilitate interpretation of GEE analyses.

Postinteraction self-report measures. We administered the same postinteraction self-report items as in Study 1, assessing participants' retrospective affect ($\alpha = .80$), their concern about what their interaction partner thought of them, and their liking for their interaction partner. All items utilized a 7-point response scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Interaction partner's rating. After the social interaction, the interaction partner (a same-gender confederate) reported how anxious the participant seemed, using a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Interaction behavior. Using a hidden camera and microphone, we recorded the social interaction. Two coders independently recorded how many questions participants asked and answered, $\alpha = .91$ and $.87$, respectively. In addition, coders recorded the total time each participant spent talking during the interaction.

Cardiovascular measures. Cardiovascular data collection methodology was consistent with Study 1, with several exceptions. We used the following equipment manufactured and/or distributed by Biopac Systems, Inc (Goleta, CA): ECG100C ECG amplifier, NICO100C noninvasive CO module, and NIBP100A noninvasive BP module. ECG signals were always detected with a Standard Lead II electrode configuration. The BP monitor was wrist mounted, collecting continual readings—every 10 to 15 s—from the radial artery

of participants' nondominant arm. Recorded measurements of cardiovascular function were stored on a computer and analyzed off-line with Biopac AcqKnowledge 3.9.2 for Macintosh software, using techniques comparable to those from Study 1. Scoring was performed blind to other participant data.

Procedure. The procedure of Study 2 was very similar to that of Study 1. In individual sessions, participants first completed the LSAS. After an experimenter applied cardiovascular sensors, participants sat quietly for 5 min. At the conclusion of the rest period, participants were told that they would be interacting with a fellow undergraduate student. Specifically, participants were instructed that the research team was interested in how two strangers interact as they get to know each other. A same-gender confederate served as the interaction partner. Confederates were trained to act as though they were taking part in a natural conversation and to give participants the opportunity to initiate topics, although confederates had also rehearsed a list of possible questions to ask (e.g., "What do you do in your spare time?"). The social interaction lasted 5 min, during which cardiovascular measurements were recorded. After the interaction, the confederate left the room and participants completed a retrospective measure of affect (i.e., affect experienced during the interaction) and the other self-report measures. Finally, the experimenter removed cardiovascular sensors and participants were thoroughly debriefed.

Results

Postinteraction self-report measures. For all postinteraction self-report measures, we conducted simultaneous regression analyses in two steps, with the following predictors: (a) trait social anxiety and gender and (b), in a subsequent model, both terms along with their interaction. For retrospective affect, the first model revealed that higher trait social anxiety predicted significantly less positive affect, $B = -0.32$, $t(177) = -5.03$, $p < .001$, $sr^2 = .13$. There was neither a significant effect of gender in the first model nor a significant two-way interaction in the second model, $ps > .20$. With respect to concern about what participants' interaction partner thought of them, the first model revealed significant effects for both trait social anxiety and gender, such that higher social anxiety predicted greater concern, $B = 0.55$, $t(177) = 4.83$, $p < .001$, $sr^2 = .11$, and men reported lower concern than did women, $B = -0.49$, $t(177) = -2.15$, $p < .05$, $sr^2 = .025$. The interaction in the second model did not reach significance, $p = .14$. Finally, for liking of the interaction partner, the first model yielded significant effects for both trait social anxiety and gender, such that higher social anxiety predicted less liking, $B = -0.15$, $t(177) = -2.13$, $p < .05$, $sr^2 = .024$, and men reported lower liking than did women, $B = -0.46$, $t(177) = -3.29$, $p < .01$, $sr^2 = .058$. The interaction in the second model was not significant, $p = .35$. In sum, for both women and men, the relationships between trait social

anxiety and the postinteraction self-report measures were consistent with those of Study 1. See Table 3 for a correlation matrix and descriptive statistics.

Interaction partner's rating. We used the same two-step regression analyses to predict the interaction partner's rating of participants' anxiety during the social interaction. The first model yielded a significant effect of social anxiety, $B = 0.25$, $t(175) = 2.06$, $p < .05$, $sr^2 = .023$, such that participants high in social anxiety seemed more anxious during the interaction than those low in social anxiety (e.g., Schlenker & Leary, 1982). There was also a significant effect of gender, $B = 0.68$, $t(175) = 2.72$, $p < .01$, $sr^2 = .040$, such that women seemed more anxious than men. The interaction in the second model did not approach significance, $p = .56$, suggesting that trait social anxiety exerted similar effects on observed anxiety among women and men.

Interaction behavior. For the number of questions asked by participants—with more questions asked reflecting a more active role in the social interaction—the first model yielded a significant effect of social anxiety, $B = -0.74$, $t(179) = -2.80$, $p < .01$, $sr^2 = .041$, such that higher social anxiety was associated with asking fewer questions of the interaction partner. A marginally significant effect of gender also emerged, $B = 0.93$, $t(179) = 1.76$, $p = .08$, $sr^2 = .016$, such that women tended to ask more questions than men. The interaction in the second model was not significant, $p = .62$.

For the number of questions answered by participants—with more questions answered reflecting a more passive role in the social interaction—the first model yielded a marginally significant effect of social anxiety, $B = 0.61$, $t(179) = 1.65$, $p = .10$, $sr^2 = .014$, such that higher social anxiety tended to be associated with answering more questions asked by the interaction partner. A significant effect of gender also emerged, $B = -2.14$, $t(179) = -2.91$, $p < .01$, $sr^2 = .044$, such that women answered fewer questions than men. The interaction in the second model was not significant, $p = .66$.

For length of time spent talking during the social interaction, neither the main effect of social anxiety in the first model nor the interaction in the second model approached significance, $ps > .16$. However, a significant main effect of gender did emerge, $B = -13.5$, $t(179) = -2.34$, $p < .05$, $sr^2 = .030$, such that women talked less than men. In sum, social anxiety was associated with similar behavior among women and men.

Task engagement. We used the same analytical strategy from Study 1, except the two-way interaction between trait social anxiety and gender was tested in a second GEE model, analogous to the regressions reported above. During the task, we observed significant increases from baseline in both HR, $B = 6.62$, $z = 15.88$, $p < .001$, and VC, $B = 2.77$, $z = 5.35$, $p < .001$, thereby justifying further investigation of challenge/threat differences. As in Study 1, however, separately predicting HR and VC reactivity revealed no significant effects for social anxiety, $ps > .42$, gender, $ps > .12$, or—in the second model—their interaction, $ps > .59$.²

Table 3. Correlations and Descriptive Statistics in Study 2

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Challenge/threat index	—													
2. TPR	-.88***	—												
3. CO	.88***	-.53***	—											
4. HR	.11	.01	.20**	—										
5. VC	.42***	-.23**	.51***	.29***	—									
6. Social anxiety	-.11	.13	-.06	-.06	-.03	—								
7. Retrospective positive affect	.13	-.10	.13	-.02	-.04	-.34***	—							
8. Concern for partner's impression	-.10	.07	-.11	.06	-.03	.36***	-.43***	—						
9. Liking for partner	-.00	-.01	-.01	.08	-.06	-.12	.29**	.06	—					
10. Partner's rating of anxiety	.11	-.08	.13	.17*	.29***	.12	-.21**	.03	-.14	—				
11. Number of questions asked	.09	-.16*	-.00	-.16*	.07	-.22**	-.00	-.03	-.08	.03	—			
12. Number of questions answered	-.06	.01	-.10	-.07	.02	.15*	-.18*	.14	-.12	.15*	-.35***	—		
13. Length of time spent talking	-.02	.05	.03	.27***	-.02	-.05	.13	.07	.26***	-.19*	-.18*	-.11	—	
14. Gender (<i>male</i> = 1, <i>female</i> = 2)	-.01	-.05	-.07	.03	-.14	.15*	.03	.21**	.22**	-.18*	-.16*	.23**	.16*	—
M	0	193.18	-0.55	6.60	2.85	3.89	4.95	3.11	5.82	3.54	5.23	11.59	125.43	1.45
SD	1	194.11	1.38	5.44	7.14	0.91	0.90	1.64	0.95	1.67	3.61	5.04	38.61	0.50

Note: TPR = total peripheral resistance; CO = cardiac output; HR = heart rate; VC = ventricular contractility. Cardiovascular values reflect the mean of reactivity scores from all task minutes.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Challenge/threat. As in Study 1, trait social anxiety was not significantly associated with the challenge/threat index during baseline, $r = .09$, $p = .22$. This suggests that cardiovascular responses did not differ as a function of social anxiety before the actual social interaction. When testing cardiovascular reactivity during the social interaction, the first model revealed only an effect for social anxiety, $B = -0.12$, $z = -1.90$, $p = .057$, such that higher social anxiety predicted cardiovascular responses consistent with greater threat. The effect for gender did not approach significance, $p = .84$. As depicted in Figure 2, the second model revealed that the effect for social anxiety was qualified by a significant interaction, $B = 0.26$, $z = 1.99$, $p < .05$. Simple effects tests revealed that higher trait social anxiety predicted cardiovascular responses consistent with greater threat for women, $B = -0.26$, $z = -2.77$, $p < .01$, but not men, $B = -0.00$, $z = -0.00$, $p = .99$. See Table 4 for descriptive statistics regarding cardiovascular measures at baseline and at each task minute.

The fact that gender and social anxiety interactively predicted only challenge/threat responses prompted us to conduct several post hoc analyses. Specifically, we explored whether the relationships between challenge/threat and other

dependent variables varied as a function of gender. We tested the interaction between the challenge/threat index (i.e., the mean across the 5 interaction minutes) and gender in standard multiple regressions predicting the noncardiovascular dependent variables. None of the interactions approached significance, $ps > .39$, suggesting that the relationships between challenge/threat and the noncardiovascular dependent variables did not differ by gender.

Discussion

Replicating Study 1 with a different measure of trait social anxiety, women and men higher in social anxiety retrospectively reported higher negative affect after a social interaction than individuals lower in social anxiety as well as greater concern about what their interaction partner thought of them and less liking for their interaction partner. In addition, women and men higher (vs. lower) in social anxiety were rated by interaction partners as seeming more anxious and—consistent with a more passive role—initiated asking fewer questions and tended to answer more partner-initiated questions during the interaction. Thus, a comprehensive set of nonphysiological measures supported predictions from

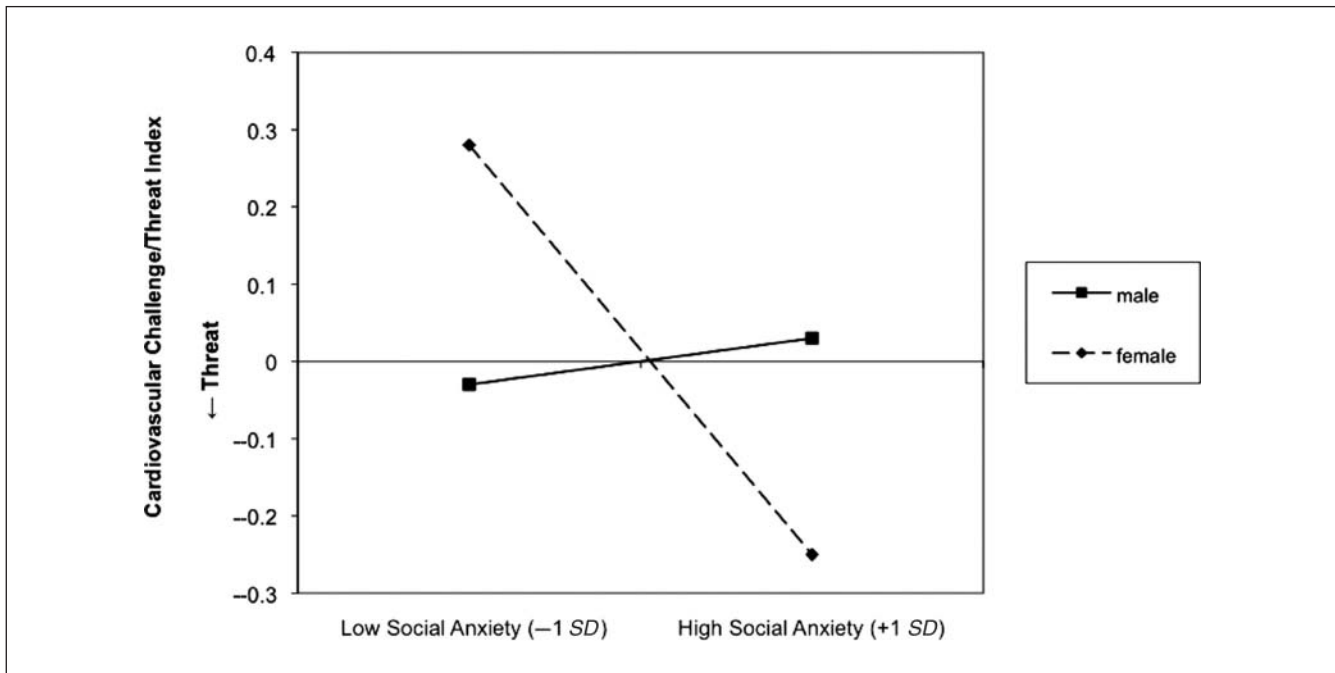


Figure 2. Challenge/threat reactivity during the social interaction task as a function of social anxiety (Liebowitz Social Anxiety Scale) and gender. Note: A lower index value indicates greater relative threat.

Table 4. Means and Standard Deviations for Cardiovascular Values During Baseline and Reactivity During Each Task Minute in Study 2

Measure	Baseline		1st task min		2nd task min		3rd task min		4th task min		5th task min	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
TPR	737.32	321.43	144.61	210.32	199.73	232.68	192.86	199.37	207.97	213.73	196.84	184.50
CO	9.97	3.62	-0.04	1.66	-0.48	1.46	-0.61	1.37	-0.63	1.40	-0.69	1.37
HR	74.26	10.77	11.19	8.10	4.97	6.22	5.29	5.68	5.52	5.34	5.82	5.50
VC	111.95	14.96	7.62	10.34	2.98	7.51	1.94	6.85	1.55	6.50	0.83	6.37

Note: TPR = total peripheral resistance; CO = cardiac output; HR = heart rate; VC = ventricular contractility.

models of social anxiety, thereby setting the stage for testing theoretically derived predictions regarding physiological responses. Predictions based on undifferentiated sympathetic nervous system activation were not supported (i.e., the lack of differences in HR and VC); however, predictions derived from a more specific model of cardiovascular responses did receive support. In particular, higher social anxiety predicted cardiovascular responses consistent with greater threat during the interaction, but only among female participants.

We thus observed a divergence for men with respect to the relationships between social anxiety and (a) self-reported responses and observed behavior versus (b) cardiovascular challenge/threat reactivity. No such divergence occurred for women, and the relationships between challenge/threat and other dependent variables did not significantly differ as a function of gender. Three possible explanations for these

results are that (a) cardiovascular challenge/threat responses function differently in women versus men, (b) women and men report social anxiety differently, and (c) women and men experience social anxiety differently. Regarding the first possibility, there is little precedent to suggest that the cardiovascular challenge/threat responses differ reliably by gender. With the exception of only a few examples for which gender played a theoretically relevant role in study design, tests of gender differences have rarely been reported because there were no meaningful effects to report.³ Although the possibility cannot be ruled out with the current data, the existing body of research does not support that cardiovascular challenge/threat responses have different psychological interpretations in men versus women.⁴

Alternatively, it is possible that men tend to misreport their social anxiety. Epidemiological studies have found lower prevalence of social phobia among men compared to

women (e.g., American Psychiatric Association, 2000). If men are more likely than women to believe that it is not socially desirable to have social anxiety, they may be reluctant to admit it. However, although the men in Study 2 reported lower trait social anxiety ($M = 3.77$, $SD = 0.87$) than did women ($M = 4.05$, $SD = 0.95$), the mean and variability in responses for men seem generally comparable to those of women, which is inconsistent with substantial underreporting. Men may also be less accurate than women at labeling (and thus reporting) trait social anxiety. Indeed, Egloff and Schmukle (2004) found that implicit measures of social anxiety were more strongly associated with explicit measures of social anxiety among women than men. Misreporting could explain why self-reported trait social anxiety did not significantly predict challenge/threat responses for men but social anxiety nonetheless predicted the behavioral measures similarly for men as for women. Thus, men who do report relatively high social anxiety may dislike social interaction and behave in ways that seem anxious to others, but their experience during social interaction may not entail actual anxiety. This explanation suggests that men may rely on different information than women when reporting trait social anxiety.

Finally, it is possible that social anxiety may function differently for women versus men during social interaction, thereby accounting for the divergence in the results for challenge/threat versus other measures for men but not women. Specifically, socially anxious women and men tend to be anxious about different aspects of social interaction. If women typically have greater relational concerns (e.g., relationships with peers) whereas men have greater hierarchical concerns (e.g., making a good impression on higher status evaluators; e.g., Baumeister & Sommer, 1997; Gabriel & Gardner, 1999; McGuire & McGuire, 1982), our experimental paradigm may have targeted women's concerns in particular, given that our interaction partners were presented as being fellow participants. The main effects that emerged for men—relative to women—to report less concern with what their interaction partner thought of them and less liking for their partner are consistent with this idea. Speculatively, then, highly socially anxious men may dislike social interaction and exhibit awkwardness that others interpret as anxiety, even when interacting with peers, because this is their typical interactional style. However, their focus on hierarchical versus relational concerns might mitigate the threat that could otherwise be experienced (see Seery et al., 2009). Conversely, different types of interactions that highlight men's hierarchical concerns could yield reliable relationships between trait social anxiety and challenge/threat among men.

General Discussion

The current studies demonstrate that trait social anxiety levels predict specific, theoretically meaningful differences in physiological response patterns during social interaction. In

Study 1, trait social anxiety predicted women's self-reported retrospective negative affect as well as physiological responses during a social interaction, such that higher social anxiety was associated with cardiovascular responses consistent with greater threat. In Study 2, whereas trait social anxiety predicted retrospective negative affect and behavioral indices of inhibition among both male and female participants, it predicted cardiovascular responses consistent with greater threat only among female participants.⁵ Based on evidence from previous studies that failed to show reliable physiological differences between people high versus low in social anxiety, the role of cognitive processes (e.g., attentional focus and negative self-schemata) has been emphasized in accounts of social anxiety (Grossman et al., 2001; Mauss et al., 2003). However, the present results indicate that well-specified physiological processes may also play an important role in social anxiety, at least among women.

The divergence in the pattern of results between measures for men further supports the potential utility of psychophysiological measures for the study of social anxiety. Observable behaviors and participant reports may be consistent with responses associated with social anxiety, but they might not always reflect the acute experience of anxiety and related states during a social interaction. Relying on only behavioral observations and participant reports may make it difficult to differentiate individuals' anxious behavior from the experience that may underlie such behavior (i.e., anxiety itself). Our approach suggests that socially anxious men may exhibit seemingly anxious responses without actually experiencing threat at the moment.

Furthermore, seemingly anxious behavior such as distancing (i.e., lower concern with interaction partners' impressions and lower liking for interaction partners) could be self-protective (cf. Murray, Holmes, & Collins, 2006). Degrading one's interaction partner and the interaction itself could allow socially anxious individuals to discount potential rejection, such as by creating a controllable attribution for it. With men's lower relational concerns relative to women, they may feel more free to engage in this strategy than women in the context of a social interaction with peers. Cardiovascular measures of challenge/threat should be well suited for further testing this possibility.

It is interesting that across two studies, there was no cardiovascular evidence of increased task engagement (HR and VC) among participants high in trait social anxiety compared to participants low in social anxiety. This need not contradict the idea that higher social anxiety is associated with heightened concern about others' opinions (e.g., Leary, 2001; Schlenker & Leary, 1982). Instead, individuals high versus low in social anxiety may find different sources of self-relevance in a social interaction, contributing to comparable levels of task engagement. For example, Seery et al. (2009) found that regardless of whether a task incentive was framed in terms of an opportunity to gain or lose, comparable task engagement resulted. However,

gain framing led to relative challenge and loss framing led to relative threat. It is possible that high social anxiety is associated with avoiding disapproval in particular, whereas low social anxiety is associated with gaining approval. This would predict the currently observed challenge/threat effects for social anxiety without necessarily resulting in task engagement differences. Future research could explicitly test this idea. However, irrespective of the underlying psychological mechanisms, our cardiovascular findings underscore the specificity of the physiological processes at work during social interaction as a function of social anxiety. Rather than leading to undifferentiated activation across the sympathetic nervous system, social anxiety may instead predict more specific patterns of physiological changes.

Our study was limited in that our participants consisted of nonclinical college undergraduates. Future research could make use of clinical samples by focusing on people who meet criteria of the *Diagnostic and Statistical Manual of Mental Disorders* (American Psychiatric Association, 2000) for social phobia. Future research might further investigate specific mechanisms that give rise to heightened threat among the socially anxious as well as to what extent our findings generalize to different types of social interactions and interaction partners and other anxiety disorders. As suggested by the current investigation, application of a theoretically driven BPS may provide important insight into the nature of social anxiety by assessing individuals' experience during an actual social interaction. Given our promising findings, it seems premature to abandon investigation of the role of physiological responses in social anxiety.

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Notes

1. We recruited only female participants in Study 1 given that Grossman, Wilhelm, Kawachi, and Sparrow (2001) observed that only women exhibited relationships between social phobia and cardiovascular responses. In Study 1, data from 10 additional participants were excluded for the following reasons: 5 because of blood pressure monitor malfunction, 4 because of poor-quality impedance cardiograph signal, and 1 because of poor-quality electrocardiograph signal. In addition, 1 participant failed to show evidence of increases in heart rate (HR) or ventricular contractility (VC) during the task and was excluded from challenge/threat analysis. In Study 2, the data from 20 additional participants were excluded: 3 because of blood pressure monitor malfunction, 12 because of poor-quality impedance cardiograph signal, 2 because of irregular heart beats that were

not possible to score reliably, 2 who failed to cooperate with instructions, and 1 who failed to complete the measure of trait social anxiety. In addition, 5 participants failed to show evidence of increases in HR or VC during the task and were excluded from challenge/threat analysis.

2. Generalized estimating equation models failed to converge for HR and VC with an unstructured correlational structure, so we instead used an exchangeable structure (i.e., a single value for correlations between minutes) with robust standard errors.
3. One study investigating gender stereotype activation in the context of women's math performance (Vick, Seery, Blascovich, & Weisbuch, 2008) predicted and found gender differences in challenge/threat, but this prediction was based on stereotype threat theory (Steele & Aronson, 1995). Activating gender stereotypes about math performance (i.e., that women are worse at math than men) should have resulted in different psychological effects for women versus men and thus cardiovascular challenge/threat differences. Another series of studies explicitly investigating gender (Mendes, Reis, Seery, & Blascovich, 2003) found that for both men and women, emotional expression led to greater challenge than emotional suppression. Furthermore, both men and women exhibited relative challenge when speaking about an emotional topic to a same-sex interaction partner but relative threat with an other-sex interaction partner. The effects of emotional expression thus varied in a parallel fashion for both men and women as a function of their interaction partner's gender.
4. Although we did not assess cortisol responses in the current research, HPA activation (of which cortisol is a product) is thought to play a role in threat's cardiovascular pattern. Findings regarding gender differences in cortisol release could thus also inform this issue. However, in a meta-analysis, Dickerson and Kemeny (2004) failed to find a reliable effect of gender on cortisol responses. This further suggests that a simple relationship between gender and physiological responses seems unlikely to explain the effects observed in Study 2.
5. Because we did not assess pretask affect in either study, it is unclear whether participants high in social anxiety experienced more negative affect specifically in response to the social interaction or if their negative affect was relatively elevated from the beginning of the study and remained elevated through the interaction.

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