ATTENTION CAPTURE AND AFFECTIVE ENGAGEMENT BY EMOTIONAL FACIAL EXPRESSIONS AND NATURALISTIC SCENES: IMPLICATIONS FOR SOCIAL ANXIETY

By

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To my family

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ATTENTION CAPTURE AND AFFECTIVE ENGAGEMENT BY EMOTIONAL FACIAL EXPRESSIONS AND NATURALISTIC SCENES: IMPLICATIONS FOR ANXIETY

By

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Pictures of facial expressions, and of affective naturalistic scenes, are widely employed in emotion research. The current study examined the extent to which these stimulus types similarly or differentially engage motivational response systems, evaluating central and peripheral physiological reactivity when faces and scenes were viewed intermixed in the same paradigm, and further investigating how self-reported social anxiety influences responding.

Sixty undergraduates viewed pictures depicting angry, neutral, and happy faces, and violent, neutral, and erotic scenes that were presented for 3 seconds each. Acoustic startle probes were presented throughout picture viewing and skin conductance, electrocortical responses (i.e., probe P300, late-positive potential), startle eyeblink magnitude, and reaction time to the startle probe were measured. Participant reports of social phobia symptoms were measured and the effects of these characteristics on reactivity were also assessed.

Results demonstrated that arousing emotional scene stimuli were associated with strong activation of appetitive and defensive responses, whereas these responses were

not engaged during processing of emotional and neutral faces. However, differences emerged when participants were grouped according to social anxiety symptom severity, as higher social anxiety was associated with increased orienting prompted by angry faces (indexed by skin conductance), enhanced attention to happy faces (indexed by probe P300 amplitude), and uniquely, greater startle reactivity when viewing both emotional expressions relative to neutral faces. Thus, although face stimuli did not seem to prompt strong motivational activation in the current free-viewing paradigm, they did distinguish between high and low social anxiety groups, demonstrating their significance for clinical research.

CHAPTER 1
INTRODUCTION

Pictures of affective facial expressions and of arousing emotional scenes capture attention and prompt reflex responses across a range of experimental paradigms. Pleasant and unpleasant naturalistic scenes, particularly when they cue survival needs or threats, have been linked to activation of motivational systems mediating appetitive and defensive behavior (Lang, 1995). Emotional facial expressions are also evolutionarily relevant stimuli that communicate fundamental social information and prompt motivated behavior (e.g., Blair, 2003; Fridlund, 1994). Neuroimaging studies indicate that similar, although not necessarily identical, brain regions are activated when individuals view both scenes and faces (Britton, Taylor, Sudheimer & Liberzon, 2006; Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002; Sabatinelli et al., 2011), and research also shows that neural and behavioral measures of attention are enhanced when participants discriminate between affective and neutral facial expressions (e.g., Eimer & Holmes, 2007; Öhman, Lundqvist, & Esteves, 2001). However, studies have generally assessed only one measure in isolation and usually require participants to perform instructed recognition or discrimination tasks. The current research examines the extent to which emotion systems are naturally engaged by facial stimuli when they are freely viewed.

A few psychophysiological studies have compared faces and scenes during passive viewing and indicate that emotional faces may prompt a less robust pattern of autonomic and somatic responding than naturalistic scenes (e.g., Alpers, Adolph, & Pauli, 2011; Surcinelli & Codispoti, 2007, published abstract). Thus, preliminary evidence suggests that facial expressions, although socially meaningful, may evoke lower levels of affective arousal and therefore less strongly engage motivational response systems. The current study aims to extend this research by comprehensively examining affective engagement across cortical responses and multiple peripheral reflex measures prompted when participants view both stimulus types within the same picture-viewing paradigm.

A second aim of this study is to investigate how the presence of social anxiety symptoms may specifically influence reactivity evoked by affective faces. Research suggests that socially anxious individuals show greater attention to affective faces, and information processing theories of clinical social phobia propose that symptoms of the disorder are in part maintained by this attentional bias (e.g., Heinrichs & Hoffman, 2001). Thus, socially anxious individuals may show a physiology indicative of increased attention and affective arousal when viewing emotional faces that is absent in non-symptomatic participants.

Affective Scenes: Robust Reactivity Across Multiple Measures

Viewing naturalistic pleasant and aversive scenes (compared to neutral) prompts a range of physiological responses that are enhanced in amplitude with increases in rated emotional intensity, or arousal. Sympathetic activation, indexed by skin conductance, is greatest when viewing high-arousing erotic or violent pictures compared to neutral content, consistent with enhanced orienting (Bradley, Codispoti, Cuthbert & Lang, 2001). The late-positive potential (LPP) component of the event-related brain potential (ERP), which peaks between 400 and 700 ms at centro-parietal scalp sites, is similarly modulated during picture viewing. Amplitude increases with increased rated picture arousal (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000), indicating prioritized visual processing of these motivationally significant stimuli (Bradley, 2009).

When brief acoustic startle probes are presented during picture viewing, it is well established that the eyeblink component of the evoked startle reflex varies with emotional valence: startle magnitude is potentiated when viewing aversive compared to neutral scenes, and relatively attenuated when viewing arousing pleasant scenes, reflecting priming of defensive and appetitive behavior, respectively (e.g., Lang & Bradley, 2010). Emotional arousal modulates these directional effects, such that defensive potentiation is augmented for the most arousing aversive content (e.g., threat, violence), and attenuation is greatest for highly arousing pleasant pictures (e.g., erotica; Bradley et al., 2001).

The startle probe also evokes a positive waveform in the ERP occurring approximately 300 ms after probe onset, maximal over centro-parietal scalp sties, which reflects attentional resource allocation (e.g., Donchin & Coles, 1988). This probe P300 response is reduced overall, as attentional resources are captured by foreground picture processing, and further reduced when pictures are emotionally arousing (Cuthbert, Schupp, Bradley, McManis, & Lang, 1998; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997). Probe P3 amplitude reduction is therefore associated with greater attentional engagement, reflecting activation of the brain's motivational circuits by affective cues.

Finally, although probe P3 is a strong index of attention allocation, it is difficult to measure at very early startle probe latencies, due to overlap with the ERP elicited by picture onset. However, attention capture at early probe latencies can also be assessed by instructing participants to make a speeded button press when they detect a startle probe and recording reaction time (RT). This measure is particularly sensitive to initial attention capture, as RT is significantly slowed when probes are presented early in picture viewing (e.g., 300ms) compared to later probes; moreover, for early probes, RT is even slower when viewing arousing pleasant and unpleasant compared to neutral images (Bradley, Cuthbert, & Lang, 1999).

Together, these conceptually overlapping measures provide a detailed profile of motivational engagement. That is, each measure indexes unique as well as cross-validating information when activated during picture processing. Heightened initial attention capture is illustrated by slowed RT to startle probes presented during emotional scenes; appetitive or defensive response mobilization are distinguished by startle reflex attenuation or potentiation, respectively, and ongoing attention to arousing emotional content is demonstrated by reduced probe P300 amplitude. The skin conductance response tracks mobilization of the sympathetic nervous system, and finally, LPP amplitude provides a brain-based measure of motivational salience, indexing the sustained “significance” of emotionally arousing cues.

Affective Facial Expressions

In contrast to the free-viewing research reviewed above, studies examining facial expression processing often employ faces as targets or distracters in tasks that frequently require discrete emotion recognition or discrimination, making it difficult to compare findings with studies using naturalistic scenes. Furthermore, researchers have employed different stimulus sets (e.g., Ekman & Friesen, 1976; Hansen & Hansen, 1998; Gur et al., 2002; Lundqvist, Flykt, & Öhman, 1998; Matsumoto & Ekman, 1989), emotional expressions (e.g., only one, or up to all 6 basic emotions; see Eimer & Holmes, 2007), and stimulus presentation latencies (e.g., 50ms to 10s; Eimer, Kiss, & Holmes, 2008; Dunning, Auriemmo, Castille, & Hajcak, 2010), which contribute to varying results. Nevertheless, data suggest in general that emotional facial expressions are relevant cues that capture attention in these specific task paradigms.

Several psychophysiological studies have directly compared emotional reactivity between free viewing of faces and scenes, and suggest that peripheral physiological responses measured during facial expression processing are less reliably modulated by affective content, compared to scenes. For example, one study reported only a slight increase in skin conductance when participants viewed happy faces compared to neutral (Alpers et al., 2011), while another demonstrated no modulation of autonomic activity by affective expression (Surcinelli & Codispoti, 2007), compared to the robust skin conductance reactivity prompted by arousing emotional scenes in both investigations. Experiments assessing startle reflex reactivity have reported that startle magnitude may be somewhat enhanced when participants view both happy and angry expressions compared to neutral faces—a different pattern than that observed for natural scenes (Alpers et al., 2011; Hess, Sabourin, & Kleck, 2007). These initial findings indicate that face stimuli may prompt only low levels affective arousal, and therefore may not evoke the same reliable and strong affective reactivity as arousing natural scenes.

Supporting this view, facial expressions have been consistently rated as lower in arousal compared to natural scenes across several experiments. In three studies (Alpers et al. 2011; Britton et al., 2006; Surcinelli & Codispoti, 2007), emotional faces have been described as modestly emotionally arousing—rated an average of 3.5 on a 9-point Likert scale also used for standardization of affective scenes (Bradley & Lang, 1994), which is similar to the average arousal ratings for neutral scenes (about 3.0 out of 9) reported in these studies.

Neural Structures Engaged During Face and Scene Processing

Another informative line of research has used functional MRI to compare free viewing of faces and scenes within the same paradigm, and suggests some overlap in the neural regions activated when participants process affective faces and scenes (Britton et al., 2006; Hariri et al., 2002). A recent meta-analysis comprehensively evaluated this finding and reported that both affective stimulus types activated the amygdala, as well as prefrontal regions, inferior temporal cortex, and extrastriate visual areas—regions that have been implicated in emotional perception (Sabatinelli et al., 2011). Yet, additional areas specific to each stimulus type were also identified, such as anterior fusiform gyrus for faces, and lateral occipital cortex for scenes (Sabatinelli et al., 2011), possibly reflecting some differences in cognitive recruitment during processing.

However, limited conclusive data are available regarding potential differences in the extent of activation prompted by faces versus scenes, data that would be helpful in assessing degree of motivational engagement. For example, it has been shown that extent of visual cortex activation—which increases with greater rated stimulus arousal—is larger when participants view arousing scenes compared to angry emotional faces; in fact, visual cortex activation was comparable between affective faces and neutral scenes (Bradley et al., 2003). Thus, again, these data suggest that motivational systems may be less strongly engaged when processing affective faces (see Hariri et al., 2002 for a counterexample regarding the amygdala).

Social Anxiety and Reactivity to Affective Faces

Although facial expressions have been rated as less arousing than scenes in normative samples, it is possible that attentional and affective responses to emotional faces are greater in persons for whom these stimuli may be of greater relevance, such as individuals reporting high social anxiety. Clinical research suggests that social phobia symptoms are associated with enhanced attention and heightened emotional reactivity to expressive facial stimuli (e.g., Heinrichs & Hofmann, 2001). Consistent with this view, studies often show that social phobia patients, compared to controls, demonstrate increased selective attention to angry facial expressions in a variety of behavioral task paradigms (e.g., Mogg & Bradley, 2002; Juth, Lundqvist, Karlsson, & Öhman, 2005; Putman, Hermans, & van Honk, 2004). Eye-tracking paradigms also show that social anxiety is associated with faster visual orienting to happy and angry face stimuli (e.g., Garner, Mogg, & Bradley, 2006; Wieser, Pauli, Weyers, et al., 2009), with further prioritized processing for angry faces (Gamble & Rapee, 2010; Horley, Williams, Gonsalvez, & Gordon, 2004), and event-related potential research demonstrates that socially anxious participants show greater LPP amplitude (Mühlberger et al., 2009), as well as enhanced ongoing selective attention (measured by steady-state visually evoked potentials) to both happy and angry facial expressions during free-viewing (McTeague, Shumen, Wieser, Lang, & Keil, 2011).

Functional imaging experiments also report that socially anxious participants show greater neural activation compared to controls when processing threatening facial expressions (amygdala, insula: Evans et al., 2008; Klumpp, Angstadt, Nathan, & Phan, 2010; Phan, Fitzgerald, Nathan & Tancer, 2006; Stein, Goldin, Sareen, Zorrilla, & Brown, 2002; Straube, et al., 2004; Straube, Mentzel & Miltner, 2005), as well as both happy and angry expressions (amygdala: Straube, Kolassa, Glauer, Mentzel, & Miltner. 2005; Yoon, Fitzgerald, Angstadt, McCarron, & Phan, 2007), further supporting the view that emotional engagement by emotional facial expressions is enhanced in social anxiety.

Finally, a recent psychophysiological investigation noted that greater self-reported social anxiety symptoms were associated with heightened startle amplitude when processing emotional social cues (both positive and negative) (Garner, Clarker, Graystone, & Baldwin, 2011), paralleling the above research on amygdala activation, and suggesting that affective facial expressions may activate peripheral physiological response systems more strongly in social anxiety. Taken together, these findings lend support to the hypothesis that emotional faces are preferentially processed in social anxiety.

The Current Study

Attention and emotional engagement were comprehensively examined when participants viewed intermixed sets of standardized happy, neutral, and angry facial expressions, and erotic, neutral, and violent natural scenes. Measures of orienting and perceptual processing known to vary with affective arousal were recorded, including skin conductance activity, late-positive potential (LPP) amplitude, and the probe P300 component. Appetitive and defensive engagement were indexed by the startle eyeblink reflex, and attention capture was measured via reaction time (RT) responses to startle probes presented during picture viewing. To assess the influence of social anxiety on reactivity to affective faces, individuals were recruited who were either high or low on self-report of social anxiety symptoms.

Hypotheses

Overall, we expected that emotional scenes would prompt greater emotional engagement than affective facial expressions. Specifically, compared to neutral scenes, erotic and violent images were predicted to prompt enhanced SCL and LPP amplitude, elicit greater probe P300 reduction and slower reaction time, and to prompt greater startle reflex potentiation and attenuation (for violent and erotic scenes respectively), whereas it was predicted that modulation of these reflexes would be much weaker during emotional face processing. Considering research showing that affective faces are generally rated in the low-arousal range in verbal reports, a separate analysis also tested the prediction that emotional faces would prompt reactivity similar to that prompted by low-arousal neutral scenes.

Following the view that affective faces are more salient emotional cues in social anxiety, we also predicted that socially anxious individuals would show greater reflex modulation than non-anxious participants when viewing affective versus neutral faces, especially in measures sensitive to attention capture, orienting and ongoing attention (e.g., RT, SCL, and probe P300). It was also specifically predicted that higher social anxiety would be associated with enhanced startle magnitude prompted by emotional faces compared to neutral, in light of recent data reporting similar results (Garner et al., 2011).

CHAPTER 2
METHOD

Participants and Screening Measures

Sixty (30 female) participants were recruited from University of Florida introductory psychology classes and received course credit for their participation. Participants were selected based on their total score on the Liebowitz Social Anxiety Scale—Self Report Version (LSAS-SR; Fresco, et al. 2001), which was administered in an initial online prescreening session. The LSAS-SR is a 24-item questionnaire assessing dimensional severity of social anxiety symptoms in a self-report format. Participants use a 4-point Likert scale to separately rate level of fear and frequency of avoidance of social interaction and performance situations over the past week. A total score of 60 has been established as the cutoff for clinically significant symptoms of generalized social phobia (Rytwinksi et al., 2009), so to ensure recruitment of high- and low-anxiety participants, those with presecreening LSAS total scores of 60 or greater, or lower than 40, were invited to participate. The measure was then re-administered at the laboratory session, and participants were assigned to high- and low-socially anxious groups according to a median split on the sample of LSAS total scores. The high-anxiety group (n=30, 21 male) reported an average total score of 67.8 (s.d.=19.1) and the low anxiety group (n=30, 11 male) reported an average total score of 23.7 (s.d.=9.0).

Materials and Design

Participants viewed a total of 108 affective pictures representing pleasant, neutral, and unpleasant content, half depicting standard emotional facial expressions (54 pictures), and half depicting naturalistic scenes (54 pictures). Emotional facial expressions were selected from the Karolinska Directed Emotional Faces Set (KDEFS;

Lundqvist et al., 1998) and naturalistic scenes from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), and all pictures depicted people. Specific hedonic content portrayed scenes of human violence, neutral people in everyday situations, and erotic couples, as well as male and female facial expressions of anger, neutral expression, and happiness. Respectively, mean(s.d.) normative ratings of arousal for pleasant, neutral, and unpleasant scenes were 6.1(0.5), 3.4(0.5), and 6.3(0.5), and were 3.6 (0.7), 2.5(0.3), and 3.8(0.7) for happy, neutral, and angry faces. Three different picture orders were used across participants so that each picture was probed at each latency and no more than 3 pictures of the same hedonic content were presented in a row.

Apparatus and Physiological Response Measurement

A PC running VPM software (Cook, 2002) and a PC running Presentation (Neurobehavioral Systems, Albany, CA) controlled data acquisition and stimulus events, respectively. Color pictures were displayed on an LCD monitor approximately 1m from the participant. Each trial began with a 3-second baseline period in which only a white fixation cross appeared on the center of the screen (gray background), then a picture was presented for 3s, followed by an inter-trial interval varying from 5 to 10 s in duration. Acoustic startle stimuli (50 ms, 98 dB) were presented over headphones during every picture at one of three latencies, either 250 ms, 750 ms, or 2500 ms after picture onset. Startle probes were also presented in one-sixth of the ITIs, occurring 5 s after picture offset.

The eyeblink component of the startle response was measured via 4mm Ag-AgCl electrodes placed over the left orbicularis oculi muscle (Fridlund & Cacioppo, 1986). The raw orbicularis EMG signal was sampled at 1000 Hz, amplified by 30,000, filtered from 28-500 Hz, and integrated (20 ms time constant). Skin conductance was recorded from 8 mm electrodes filled with .5 M NaCl paste on the hypothenar eminence of the left palm. Raw skin conductance data was continuously sampled at 20 Hz.

Event-related potentials were sampled at 250 Hz using a 129-sensor dense array EEG system. Signals were bandpass filtered (0.1-100 Hz) with a vertex reference. Data were then filtered off-line at 30 Hz and transformed to an average reference. For analysis of the probe-P300 component, stimulus-locked epochs were extracted from 100 ms before to 600 ms after startle probe onset and were baseline-corrected (100 ms pre-startle onset). For analyses of the late-positive potential (LPP) elicited by picture onset, epochs time-locked to picture onset were also extracted and baseline corrected (100 ms before to 800 ms after picture onset). Reaction time was recorded in milliseconds via a serial-port button press device communicating with the VPM data acquisition computer.

Procedure

Participants were comfortably seated in a sound-attenuated room, where they initially completed the LSAS-SR before the researcher applied sensors and headphones. Partcipants were instructed that pictures would be displayed on the screen, and that they should look at each picture for the duration of its presentation. They were informed that brief noises would be intermittently presented over the headphones and that they should quickly press the provided button each time a noise was detected.

Data Reduction

For startle magnitude, eye blink data were reduced off-line using a peak-scoring algorithm that determines peak values for onset latency and amplitude (Balaban, Losito, Simons, & Graham, 1986). Trials with clear artifacts were rejected and trials with no responses scored as zero magnitude blinks. The average raw startle magnitude was calculated across probes presented during the inter-trial interval (ITI), and all raw startle magnitudes were deviated from this ITI value and converted to T-scores (mean=50=ITI, s.d.=10). Average startle magnitude was computed over the two later startle probe times (750ms, 2500ms) separately for each stimulus type (face/scene) and valence (pleasant/neutral/unpleasant) for each participant.

Raw skin conductance data was converted into microSiemens and averaged into half-second bins. These values were computed as change scores relative to the 1 second prior to picture onset, and the maximum skin conductance change between 1 and 6s after picture onset was determined. Average maximum change scores were computed for each stimulus type and valence for each participant.

For event-related potentials, artifact-free EEG segments were extracted and probe P300 amplitude was calculated as the mean positivity over 24 centro-parietal sensors in a window from 260-340ms after startle probe onset, relative to the 100 ms pre-startle baseline. Average P300 amplitude was calculated across the two later (750, 2500ms) startle probe times for each stimulus type and valence. Because P300 reduction is associated with greater attention to the picture, the data were multiplied by –1 so that greater P3 reduction was characterized by a more positive value. The late positive potential elicited by each picture was measured as the average baseline-corrected cortical positivity between 400 and 700 ms after picture onset, over 36 centro-parietal sensors. Average LPP amplitude was computed for each stimulus type and valence.

For RT data, a log transformation was used to normalize the distribution of raw RT values. Average RT was computed for each startle probe time (250, 750, 2500ms), stimulus type, and valence.

Data Analysis

Data were analyzed using SPSS (Version 17.0). We performed a multivariate profile analysis for examination of skin conductance, LPP, and probe P300 measures, as these index specific aspects of orienting that are similarly modulated by rated stimulus arousal. A 3(measure: skin conductance, LPP, probe P300) x 2(stimulus type: face, scene) x 3(valence: pleasant, neutral, unpleasant) x 2(group: low, high anxious) design was used. To assess affective engagement, startle magnitude was analyzed using a 2(stimulus type: face, scene) x 3(valence: pleasant, neutral, unpleasant) x 2(group: low anxious, high anxious) univariate repeated-measures ANOVA. Attention capture across time, measured by RT, was assessed using a 3(time: 250, 750, 2500ms) x 2(type) x 3(valence) x 2(group) univariate repeated-measures ANOVA. Greenhouse-Geisser corrections accounted for multiple comparisons.

To test the prediction that emotional faces prompt affective reactivity similar to that prompted by neutral scenes, activity within each dependent measure (skin conductance, LPP amplitude, probe P300 amplitude, reaction time at 250ms, and startle magnitude) was first averaged over happy and angry face conditions. This was compared to reactivity within each measure during neutral scene processing in a 5 (measure) x 2 (content: emotional faces, neutral scenes) multivariate ANOVA. Follow-up t-tests then examined whether the difference between these two conditions (emotional face minus neutral scene) was significantly different from zero.

CHAPTER 3
RESULTS

Faces and Scenes: Skin Conductance, LPP, Probe P3

Consistent with the prediction that emotional scene stimuli more robustly engage motivational systems than emotional faces, affective modulation was only significant when participants viewed scenes, across measures indexing orienting, motivational significance, and ongoing attention allocation, Type x Valence: $F(2,57)=15.4$, $p<0.001$, $\eta^2_p=0.35$; see Figure 1. Specifically, when viewing erotic and violent scenes compared to neutral scenes, skin conductance was significantly increased, $F(2,57)=5.7$, $p<0.01$, $\eta^2_p=0.17$, LPP amplitude was significantly enhanced, $F(2,57)=23.1$, $p<0.001$, $\eta^2_p=0.45$, and there was greater reduction of probe P3 amplitude, $F(2,57)=36.8$, $p<0.001$, $\eta^2_p=0.56$.

As expected, these measures were not significantly modulated by facial expression content, as neither skin conductance, nor LPP amplitude, nor probe P3 reduction significantly differed among happy, angry, and neutral faces, all Fs[2,57]<2.6, n.s. ERP waveforms illustrating LPP and probe P3 modulation are provided in Figures 2 and 3, respectively. The strong responses prompted by emotional scenes was also apparent overall, as skin conductance was increased, LPP amplitude more enhanced, and probe P3 amplitude more reduced overall when viewing all scenes versus faces, Type, $F(1,58)=79.8$, $p<0.001$, $\eta^2_p=0.58$. Emotional modulation unique to natural scenes also drove an overall effect of picture Valence, $F(2,57)=41.0$, $p<0.001$, $\eta^2_p=0.81$.

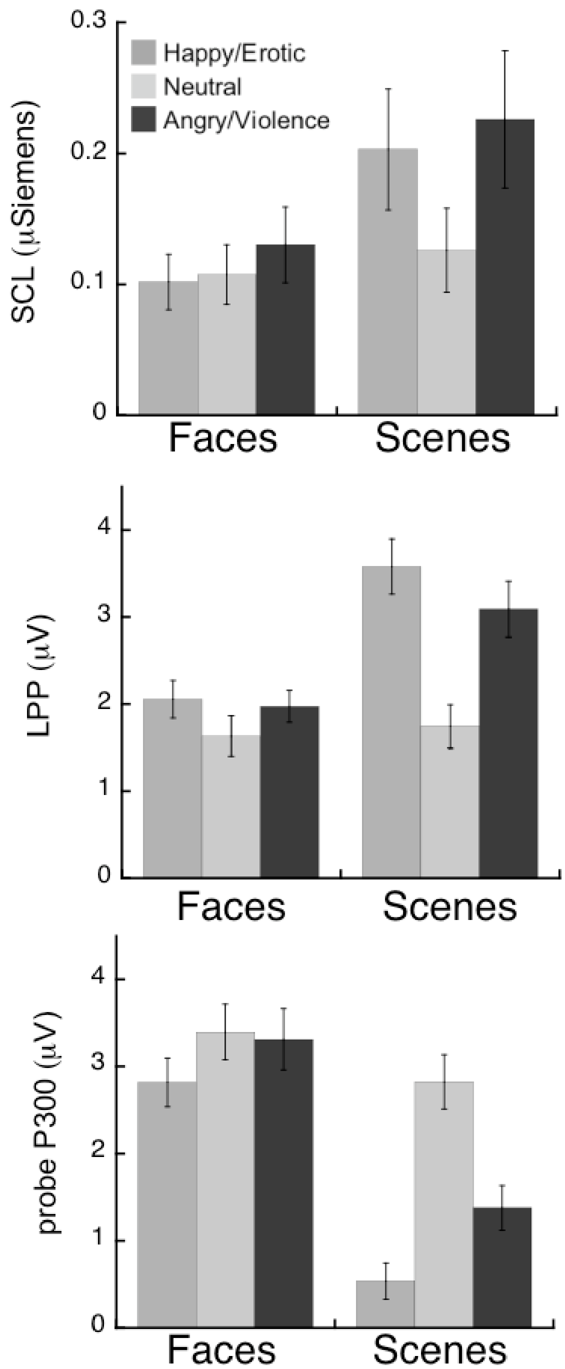

Figure 2-1. Average electrodermal and electrocortical reactivity when participants viewed happy, neutral, and angry facial expressions, as well as erotic, neutral, and violent natural scenes. Top panel: average maximum change in skin conductance level (SCL). Middle panel: average scalp positivity elicited by picture onset, over centro-parietal sensors in the late positive potential window (LPP; 400-700ms). Bottom panel: average scalp positivity elicited by startle probe onset, over centro-parietal sensors in the probe P300 window (240-360ms). Error bars represent standard error of the mean.

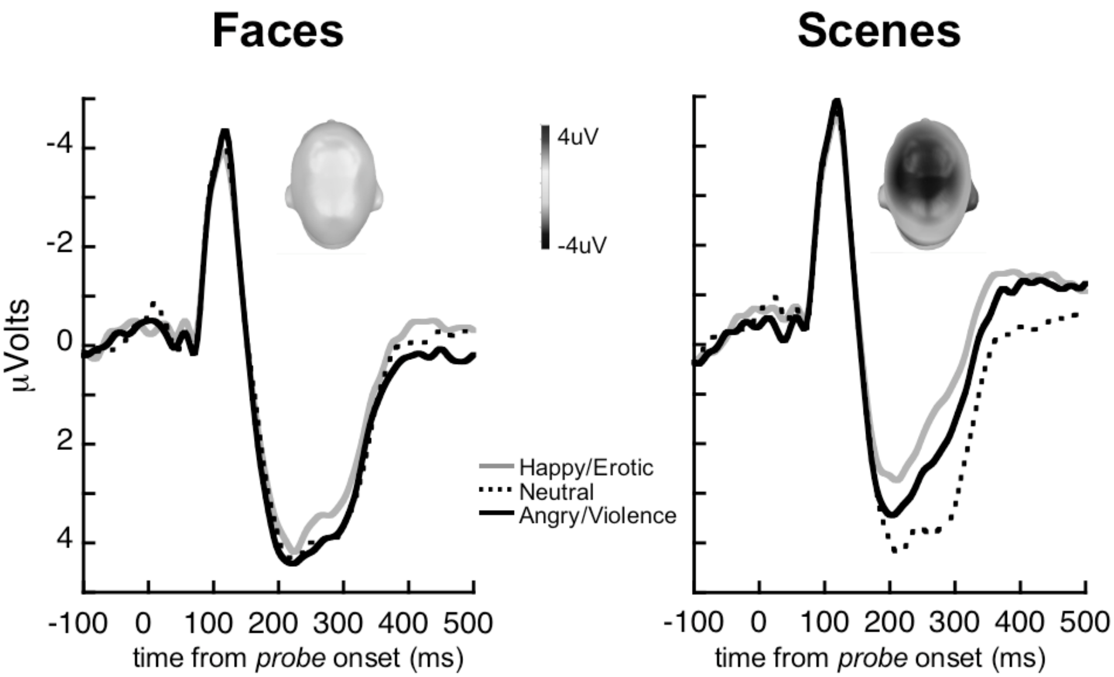

Figure 2-2. Grand average ERP waveforms (24 centro-parietal sensors) elicited by acoustic startle probes that were presented when participants viewed happy, neutral, and angry facial expressions, and erotic, neutral, and violent scenes. Insets depict the scalp topography (top view) of the difference between emotional (pleasant and unpleasant) and neutral picture processing for each stimulus type, in the probe P300 window (240-360ms).

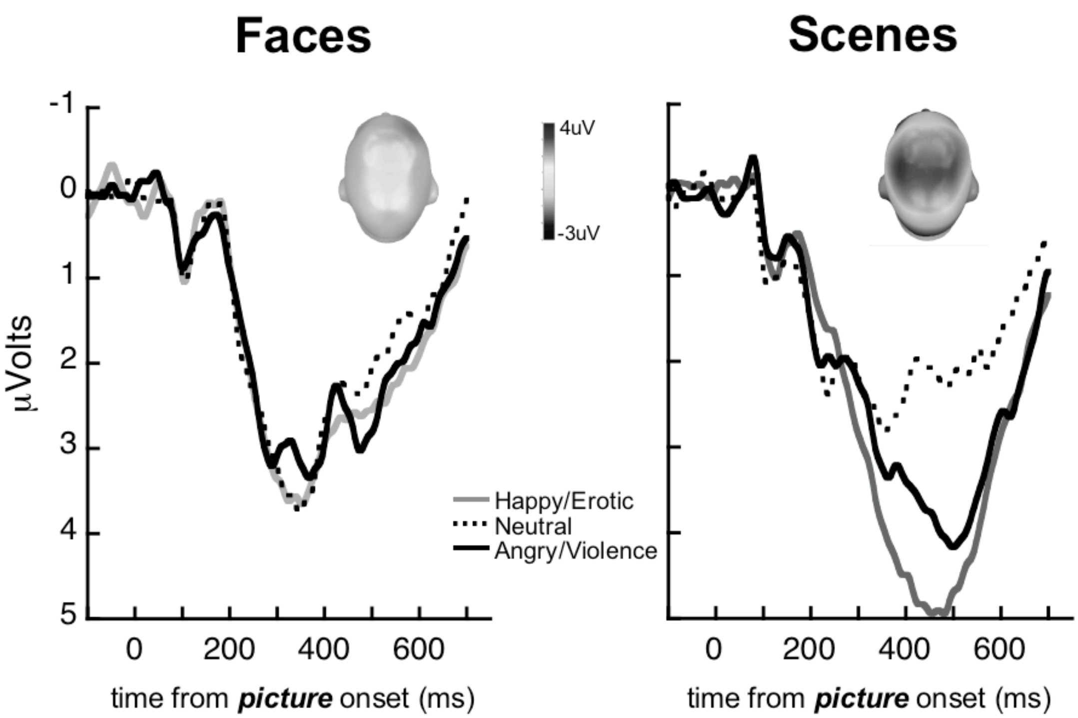

Figure 2-3. Grand average ERP waveforms (32 centro-parietal sensors) elicited by picture onset when participants viewed happy, neutral, and angry facial expressions, and erotic, neutral, and violent scenes. Insets depict the scalp topography (top view) of the difference between emotional (pleasant and unpleasant) and neutral picture processing for each stimulus type, in the late positive potential window (400-700ms).

Faces and Scenes: Probe Reaction Time

Also as predicted, probe reaction time was slower when participants viewed violent and erotic scenes compared to neutral scenes, $F(2,57)=7.5$, $p<0.01$, $\eta^2_p=0.21$, whereas emotion expression content did not affect RT for face stimuli, $F(2,57)<1$, Type x Valence: $F(2,116)=6.0$, $p<0.01$, $\eta^2_p=0.09$. This effect was most salient at the earliest probe latency (250ms) during picture viewing, Valence x Time: $F(4,232)=6.7$, $p<0.001$, $\eta^2_p=0.10$ (see Figure 5, inset), consistent with previous studies (Cuthbert et al., 1998).

As illustrated in Figure 4, analyses across time showed a general waning of attentional resource allocation to the picture stimulus as viewing persisted. RT was slowest at 250ms after picture onset, followed by 750 ms and 2500 ms, Time: *F*(2,116)=58.4, *p*<0.001, η^2_p=0.50 (all comparisons p<0.001). Probe RT was also slower overall when viewing naturalistic scenes compared to facial expressions, Type: *F*(1,58)=45.0, *p*<0.001, η^2_p=0.44, and although RT was significantly slower for scenes versus faces at all probe times (*F*s[1,58]>7.1, *p*s<0.01) this difference was greatest early during picture viewing when attention capture is strongest, Time x Type: *F*(2,116)=16.2, *p*<0.001, η^2_p=0.22; effect sizes (h2p) at each probe time were 0.55, 0.22, and 0.11, respectively.

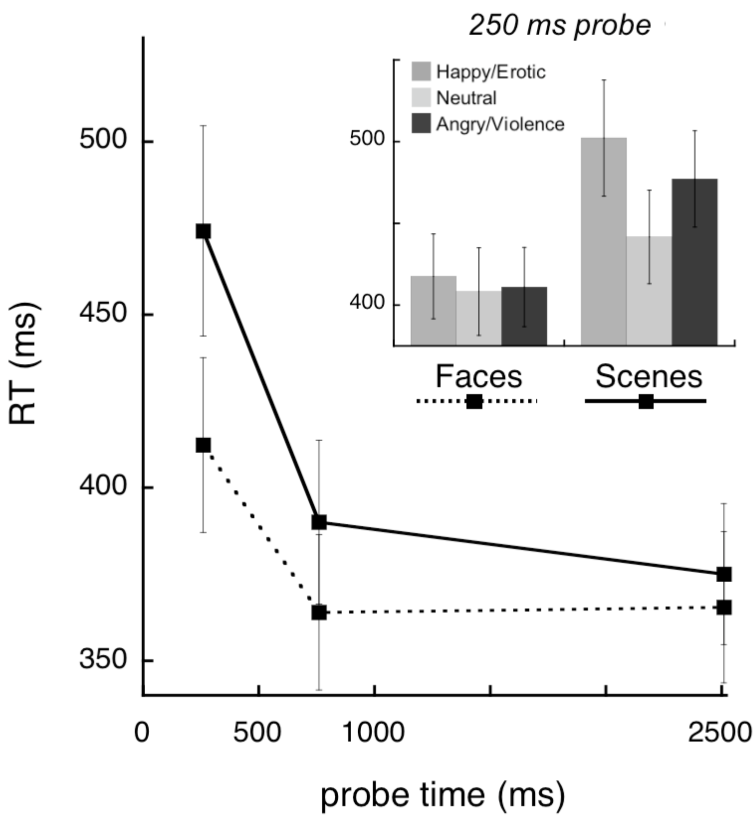

Figure 2-4. Reaction time to acoustic startle probes that were presented 250 ms, 750 ms, or 2500 ms into the picture-viewing period, averaged separately for facial expression and naturalistic scene stimuli. Inset illustrates mean RT at the early (250ms) probe time when participants viewed happy, neutral, and angry faces, and erotic, neutral, and violent scenes. Error bars represent standard error of the mean.

Faces and Scenes: Startle Magnitude

Illustrated in Figure 5, robust appetitive and defensive modulation was only observed when participants viewed natural scenes, as expected, Type x Valence: $F(2,116)=15.8$, $p<0.001$, $\eta^2_p=0.22$. Specifically, startle reflexes were strongly potentiated when processing violent compared to neutral scenes and were attenuated when viewing erotic scenes compared to neutral (all comparisons $p<0.01$, Valence within scenes: $F[2,116]=18.5$, $p<0.001$, $\eta^2_p=0.22$). For face stimuli, startle magnitude was relatively greater when participants viewed both happy and angry expressions compared to neutral faces (quadratic contrast: $F[1,59]=3.9$, $p<0.05$), and the size of this modulation effect was relatively smaller compared to the effect for scenes, Valence within faces: $F(2,116)=3.1$, $p=0.05$, $\eta^2_p=0.05$. The strong affective startle modulation observed for natural scenes was also apparent in an overall effect showing that startle reflex magnitude was greater, on average, when viewing unpleasant images compared to neutral and pleasant images, Valence: $F(2,116)=8.8$, $p<0.001$, $\eta^2_p=0.13$ (unp v. neu, pl contrasts ps<0.004).

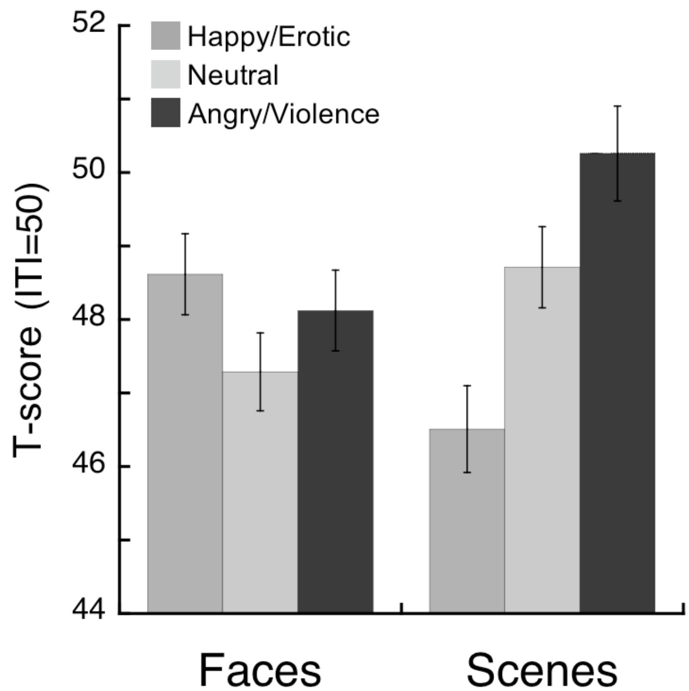

Figure 2-5. Average startle reflex magnitude over acoustic probes presented 750ms and 2500ms after picture onset, while participants viewed happy, neutral and angry facial expressions, as well as erotic, neutral, and violent naturalistic scenes. Error bars represent standard error of the mean.

Follow-up Analysis: Affective Faces v. Neutral Scenes

As predicted, affective reactivity across most measures was similar when participants viewed emotional faces to reactivity that was prompted by neutral scenes. Specifically, skin conductance, probe P300, LPP, and startle reflex magnitude responses did not significantly differ between emotional face and neutral scene conditions, all *F*s<1.3, n.s, and follow-up t-tests confirmed that this difference was not significantly different from zero for these measures, *t*s(59)<1.2, n.s. Only probe RT was slower when viewing neutral scenes compared to emotional faces early in picture viewing, $F(1,59)=14.0$, $p<0.001$, $\eta^2_p=0.19$, Measure x Content: $F(4,56)=3.1$, $p<0.05$, $\eta^2_p=0.18$, suggesting relatively greater attention capture by neutral scenes.

Effects of Social Anxiety

As shown in Figure 6, and supporting the prediction that affective facial expressions are associated with greater attentional and affective responses in social anxiety, the high anxious group demonstrated enhanced skin conductance when viewing angry faces compared to neutral and happy, (quadratic contrast: $F[1,29]=6.7$, $p<0.02$, $\eta^2_p=0.19$) suggesting heightened orienting to threatening expressions. This group also showed reliably greater reduction in startle probe P3 amplitude when viewing happy versus neutral and angry faces, quadratic contrast: $F(1,29)=8.8$, $p<0.05$, $\eta^2_p=0.17$, reflecting heightened attention allocation to these stimuli. In contrast to the high anxious group, and as predicted, participants reporting low social anxiety showed no significant modulation of skin conductance, probe P3, or LPP measures when viewing emotional facial expressions (all Valence effects: Fs[2,57]<1.5, n.s.; Group x Measure x Type x Valence effect approached significance: $F[4,55]=1.9$, $p=0.06$, $\eta^2_p=0.12$, two-tailed).

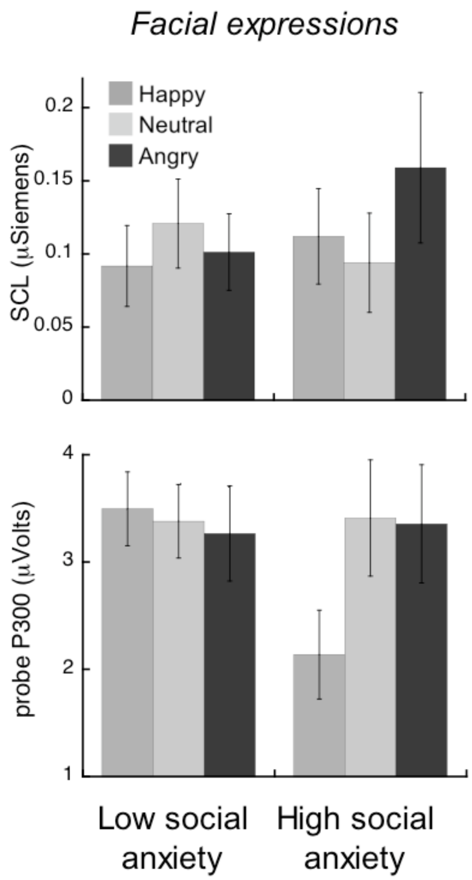

Figure 2-6. Skin conductance and startle probe P300 modulation for facial expression stimuli only, comparing high and low socially anxious groups. Top panel shows the average maximum change in skin conductance level when participants viewed happy, neutral, and angry facial expressions. Bottom panel shows the average scalp positivity elicited by startle probe onset, over centro-parietal sensors in the probe P300 window (240-360ms), when participants viewed happy, neutral, and angry faces. Error bars represent standard error of the mean.

Regarding startle reflex modulation, the overall interaction by Group was non-significant, *F*<1, n.s. However, the planned independent tests showed that the high social anxiety group demonstrated heightened startle magnitude when viewing angry ($p<0.01$) and happy ($p<0.01$) expressions compared to neutral faces, $F(2,58)=5.6$, $p<0.01$, $\eta^2_p=0.17$, as predicted, and as illustrated below in Figure 7. For the low social anxiety group, startle magnitude did not significantly differ between emotional and neutral contents.

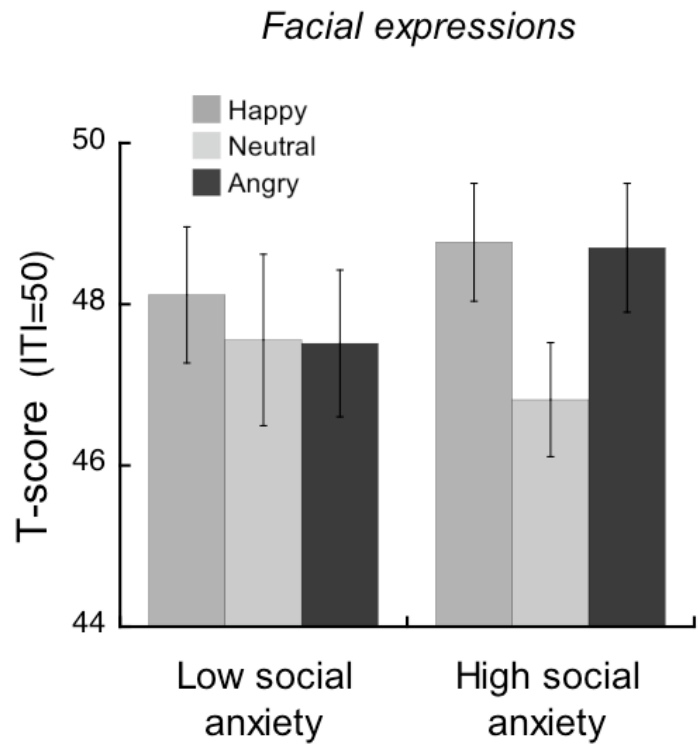

Figure 2-7. Startle reflex magnitude for facial expression stimuli only, comparing high and low socially anxious groups. Error bars represent standard error of the mean.

Probe reaction time did not significantly differ between anxiety groups (all Fs<2.9, n.s.), suggesting that this measure of attention capture by face stimuli was not influenced by social anxiety in this sample.

Finally, as predicted, both anxiety groups showed reliably enhanced skin conductance, reduced probe P3 amplitude, and increased LPP amplitude when viewing erotic and violent compared to neutral naturalistic scenes, showing that reactivity to standard survival cues did not differ between groups, all Valence effects: $F(2,57)>2.5$, $p<0.05$. See Tables 1 and 2 for a summary of mean reactivity within each physiological measure (Table 2-1) and RT (Table 2-2) across conditions, compared between high and low anxious groups.

Table 2-1. Mean physiological reactivity when viewing faces and scenes, by anxiety group.

	Low social anxiety (n=30)			High social anxiety (n=30)		
	Pleasant	Neutral	Unpleasant	Pleasant	Neutral	Unpleasant
Skin conductance (μS)						
Faces	0.1*(0.03)*	0.1*(0.03)*	0.1*(0.03)*	0.1*(0.04)*	0.1*(0.03)*	0.2*(0.04)*
Scenes	0.2*(0.03)*	0.1*(0.03)*	0.2*(0.05)*	0.2*(0.09)*	0.1*(0.06)*	0.3*(0.1)*
Late positive potential (μV)						
Faces	2.3*(0.3)*	1.7*(0.3)*	2.1*(0.5)*	1.8*(0.3)*	1.6*(0.4)*	1.9*(0.2)*
Scenes	3.8*(0.5)*	2.0*(0.3)*	3.4*(0.5)*	3.3*(0.4)*	1.5*(0.4)*	2.8*(0.4)*
Probe P300 (μV)						
Faces	3.5*(0.3)*	3.4*(0.3)*	3.3*(0.4)*	2.1*(0.4)*	3.4*(0.5)*	3.4*(0.6)*
Scenes	0.7*(0.3)*	3.2*(0.4)*	1.3*(0.2)*	0.4*(0.3)*	2.4*(0.5)*	1.5*(0.5)*
Startle magnitude (*T*-score)						
Faces	48.1*(0.8)*	47.6*(1.1)*	47.5*(0.9)*	48.8*(0.7)*	46.8*(0.7)*	48.7*(0.8)*
Scenes	46.1*(0.9)*	49.3*(0.9)*	50.0*(1.2)*	46.8*(1.0)*	48.3*(0.8)*	50.4*(0.8)*

Mean (s.d.) activity within each psychophysiological measure when high and low socially anxious participants viewed Happy (Pleasant), Neutral, and Angry (Unpleasant) facial expressions, and Pleasant, Neutral, and Unpleasant naturalistic scenes. μS=microSiemens; μV=microvolts. For *T*-score, 50=mean startle magnitude during inter-trial interval.

Table 2-2. Mean reaction time across the picture viewing period, by anxiety group.

	Low social anxiety (n=30)			High social anxiety (n=30)		
	Pleasant	Neutral	Unpleasant	Pleasant	Neutral	Unpleasant
250 ms probe time						
Faces	421*(35)*	412*(35)*	408*(31)*	414*(38)*	404*(40)*	414*(36)*
Scenes	486*(39)*	424*(33)*	477*(40)*	519*(58)*	460*(46)*	478*(43)*
750 ms probe time						
Faces	365*(29)*	371*(31)*	388*(31)*	352*(33)*	340*(33)*	367*(35)*
Scenes	387*(31)*	390*(34)*	381*(31)*	416*(40)*	381*(33)*	386*(34)*
2500 ms probe time						
Faces	356*(26)*	373*(28)*	365*(29)*	368*(39)*	365*(35)*	366*(31)*
Scenes	374*(30)*	386*(31)*	373*(27)*	377*(28)*	380*(34)*	362*(29)*

Mean (*s.d.*) reaction time (in milliseconds) for instructed button presses to acoustic startle probes that were presented 250ms, 750ms, and 2500ms after the onset of a picture stimulus. Data are shown separately for high and low socially anxious participants when viewing Happy (Pleasant), Neutral, and Angry (Unpleasant) facial expressions, and Pleasant, Neutral, and Unpleasant naturalistic scenes.

CHAPTER 4
DISCUSSION

The present study examined attention and affective engagement when participants viewed standardized emotional and neutral facial expressions and naturalistic scenes intermixed within the same paradigm. Results demonstrated that processing arousing pleasant and unpleasant stimuli was associated with strong activation of appetitive and defensive responses, whereas these responses were not reliably engaged during processing of emotional and neutral faces—a finding that has been suggested by previous autonomic physiology data (Surcinelli & Codispoti, 2007, published abstract). Face stimuli were nevertheless effective in demonstrating reactivity differences between high and low socially anxious groups, which is consistent with previous research showing that responses to affective face cues are heightened in social anxiety.

Reactivity Across Multiple Measures

Viewing erotic and violent scenes prompted a physiological profile that has been observed in many previous studies. Skin conductance increased when processing emotional compared to neutral scenes, demonstrating heightened orienting to these arousing pictures (e.g., Bradley et al., 2001; Bradley, 2009). Similarly, the late positive potential was augmented when participants viewed pleasant and unpleasant scenes, reflecting the motivational salience of these cues compared to neutral (Bradley, 2009; Ferrari, Bradley, Codispoti, & Lang, 2011). P300 amplitude elicited by startle probes was significantly reduced during erotic and violent images, showing that attention allocation was prioritized toward motivationally relevant foreground stimuli throughout the viewing interval (e.g., Schupp, et al., 1997). Participants were also much slower to make a button press in response to probes presented early (250ms) during arousing scenes compared to neutral, showing strong initial attention capture (Cuthbert et al., 1998). Finally, startle magnitude was reliably potentiated during processing of violent scenes, reflecting defensive activation, and consistently attenuated during erotic scenes, reflecting appetitive activation (e.g., Lang & Bradley, 2009). These data together are in line with the theory that arousing naturalistic scenes representing strong motivational cues evoke physiological reactions that prepare appetitive or defensive action (Lang et al., 1997).

In contrast, strong reflex modulation was not apparent when participants processed faces. Neither happy nor angry faces prompted sympathetic orienting, enhancement of perceptual processing, or attentional resource allocation that was significantly different from reactivity during neutral face viewing. These findings parallel previous data reporting a lack (or very limited evidence of) autonomic responding prompted by emotional faces (Alpers et al., 2011; Surcinelli & Codispoti, 2007). Results are furthermore consistent with neuroimaging data showing that extent of visual cortex activation is greater when participants process high arousing erotic and violent images, in contrast to angry facial expressions (Bradley et al., 2003).

Attention capture, measured by probe RT in the present study, was also not significantly influenced by facial expression content, in contrast to research showing that emotional faces capture heightened attention in other paradigms (e.g., Eimer & Holmes, 2007; Mogg & Bradley, 2002; Öhman et al., 2001). It is important to highlight that attention paradigms often require discrete emotion recognition or discrimination and include tasks that instruct attention toward face stimuli, such as matching, visual search, or oddball tasks. Therefore, reaction time and ERP modulation reported in previous studies could reflect active emotion recognition or discrimination, whereas the spontaneous, strong engagement observed for emotional scenes was not apparent for faces in the current free-viewing context.

Finally, startle magnitude was somewhat greater for the whole sample when participants processed happy and angry faces compared to neutral; however, this effect was weaker than modulation observed for emotional scenes. A similar pattern has been reported in previous studies (Alpers et al., 2011; Hess et al., 2007), and may be consistent with the view that faces prompt low affective arousal and therefore do not strongly prime motivational systems in either the appetitive or defensive direction. It is also possible that, as affective faces are typically rated slightly higher in arousal than neutral faces (e.g., Surcinelli & Codispoti, 2007), these pictures may prompt slightly enhanced general arousal that increases reflex responding (see Van Eekelen, Garner, Berg, & Boswell, 1993; published abstract) but does not activate action preparation systems to the point of robust startle modulation. Prior research correspondingly suggests that a sufficiently high level of affective arousal (i.e., at least the moderate range) is necessary to prompt significant startle reflex attenuation and potentiation (Cuthbert, Bradley, & Lang, 1996). Additional research is certainly necessary to make stronger conclusions regarding startle reactivity to affective faces, considering that multiple processes are known to influence startle magnitude (Bradley, Codispoti, & Lang, 2006). However, it is clear that these stimuli do not activate appetitive or defensive mobilization in the same manner as arousing scenes.

Faces Compared to Neutral Scenes

For the participant group as a whole, reactivity prompted by emotional faces was generally equivalent to that elicited when processing neutral pictures depicting people performing everyday tasks. Happy and angry facial expressions prompted orienting responses comparable to these neutral scenes (indexed by skin conductance), and stimulus types were also similar in their degree of motivational salience, as indexed by LPP amplitude. Probe P3 data showed that ongoing attention allocation was similar whether participants viewed emotional faces or neutral scenarios. Startle magnitude was also similar between the two conditions, again suggesting defensive action preparation mechanisms were likely not reliably primed by emotional faces. However, initial attention capture (indexed by RT to startle probes at 250ms) was heightened during neutral scenes compared to emotional faces, which likely reflects that scene stimuli necessarily contained more perceptual and contextual information, therefore capturing additional processing resources (e.g., Lavie & Tsal, 1994). Despite perceptual differences between stimulus types, however, these data suggest that affective faces prompt relatively low motivational drive (see Cuthbert et al., 1996; LeDoux, 1989), and overall reduced reflex reactivity during free-viewing.

Social Anxiety and Facial Expressions

Although reactivity prompted by facial expressions was weak across the entire sample, when participants were grouped according to self-reported social anxiety, higher symptom reports were associated with greater reactivity to affective faces. The high anxiety group showed enhanced skin conductance when viewing angry facial expressions, whereas conductance in the low-anxious group was similar across all faces. This finding suggests that threatening expressions prompt augmented orienting responses in social anxiety, and is supported by previous studies showing enhanced visual orienting to and scanning of angry faces in social phobia patients (e.g., Gamble &

Rapee, 2010), as well as narrative imagery data showing increased sympathetic activation when patients imagine aversive social cues (e.g., McTeague et al., 2009).

The high social anxiety group also demonstrated significantly reduced startle probe P3 amplitude when viewing happy compared to neutral and angry faces, whereas the low anxious group did not. This finding somewhat supports the view that selective attention to affective faces is heightened in social anxiety, as in studies reporting enhanced P1 and ssVEP amplitude for happy and angry faces in anxious participants (e.g., Mühlberger et al., 2009; McTeague et al., 2010). Whereas the high social anxiety group here did not show reduced probe P3 during angry face processing in the overall average, inspection of individual response patterns showed that 72% of high-anxious individuals did demonstrate reduced probe P3 amplitude when viewing happy, angry, or both emotional expressions compared to neutral, providing some evidence that affective faces prompt greater attention allocation in social anxiety. It should also be noted that the present high social anxiety group reported somewhat lower symptom severity (mean LSAS score=63) compared to previous samples (e.g., McTeague et al., 2010, mean LSAS score=73), suggesting that a more reliable pattern of enhanced attentional responding might be observed in a treatment-seeking social anxiety group.

Finally, startle results suggested that the high social anxiety group was the source of the overall startle modulation effect observed in the whole-sample analysis. Whereas the high anxious group showed significantly increased startle reflex magnitude when processing both happy and neutral facial expressions compared to neutral, the low social anxiety group did not show this difference. This finding parallels a recent study showing that increased self-reported social anxiety was associated with greater startle magnitude when processing both positive and negative social cues (Garner et al., 2011). It may also be considered that larger startle responses during affective face viewing in the overall sample could have been driven by higher social anxiety participants' responses. Research reporting that social anxiety patients show greater amygdala activation than controls when viewing affective faces (e.g., Campbell et al., 2007; Yoon et al, 2007) supports these startle results in suggesting that, in fact, defensive response systems might be engaged by emotional face stimuli to a greater extent in individuals for whom these cues are more fear-relevant and potentially more arousing. However, it is important to note here that LPP amplitude prompted by affective faces did not significantly differ between high- and low-anxious groups. As the LPP has been shown to be a reliable index of affective salience and motivational relevance (Bradley, 2009; Ferrari et al., 2011), it is difficult to strongly conclude that defensive reflex systems are robustly engaged, without strong evidence of increased motivational significance.

Taken together, these effects illustrate that facial expressions can be effective stimuli for demonstrating differences in emotional responding between anxious and non-anxious participants, even in a non-treatment-seeking student sample. Lissek and colleagues (Lissek, Pine, & Grillon, 2006) have suggested that less potent affective cues (as faces were shown to be here) may be better suited for distinguishing patterns of affective reactivity between anxiety patients and controls. That is, highly arousing affective pictures—which depict more directly survival-relevant information—strongly engage motivated attention (Lang, Bradley, & Cuthbert, 1997) in all participants. Indeed, both high and low anxious groups in the current study showed the same robust patterns of affective physiology when viewing naturalistic scenes, demonstrating that adaptive emotional reflexes are unaffected by social anxiety symptoms, whereas orienting and attentional responses to social stimuli are somewhat heightened for those reporting increased social fear. This finding is also consistent with previous data showing that social phobia patients do not differ from controls in reactivity when imagining standard scenes of survival threat (Cuthbert et al., 2003; McTeague et al., 2009), and data demonstrating that patients with anxiety disorder diagnoses generally show heightened reactivity to ambiguous, less imminent threat cues (see Lissek et al., 2006 for a review).

Conclusions and Implications

Compared to evocative naturalistic scenes, standardized facial expressions prompt limited activation of motivational response systems when both faces and scenes are viewed together in the same paradigm. Faces are lower-arousal, less affectively engaging stimuli; nevertheless, the present research demonstrates that they can be effective in distinguishing between high and low social anxiety groups, for whom these cues are disorder-relevant.

As noted here, it has been difficult to assess the intrinsic emotional salience of face stimuli, given that they have generally been presented in the context of many different tasks. It will therefore be important to examine how affective reactivity observed in this study relates to neural activation patterns reported in previous investigations. Follow-up brain imaging research using the current paradigm could more closely assess motivational circuit activation and connectivity during face and scene processing. Additionally, extent of activation could be directly compared between faces and low as well as high arousal scenes, to more thoroughly investigate the relationship between degree of circuit activation and associated peripheral physiological responses.

Such comprehensive specification of brain and body responses can also illustrate detailed profiles of affect system activation in social anxiety, and therefore continue to inform clinical research.

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BIOGRAPHICAL SKETCH

Dr. Wangelin received her Ph.D. from the University of Florida in the summer of 2012. Her interests in anxiety disorders and emotion science began during her undergraduate study at the University of North Carolina at Chapel Hill, where her first research experience involved examining video-feedback as a tool in the behavioral treatment of social phobia. She also completed honors thesis work on a neuroimaging project investigating the neural correlates of facial emotion perception in schizophrenia. Cultivating her interests in emotion neuroscience, she pursued post-baccalaureate training at the NIMH Center for the Study of Emotion and Attention at the University of Florida in 2004, where she learned psychophysiological and electroencephalographic methods. She then began graduate work at the NIMH-CSEA in 2006 as a doctoral student in the Department of Clinical and Health Psychology. Her master's research, completed in 2008, entailed a multi-measure investigation of the effect of distraction on neural and physiological indices of affective engagement. She also advanced a second line of research examining emotional reactivity to threat of respiratory distress as it applies to interoceptive fear in panic disorder. Dr. Wangelin's clinical work emphasized evidence-based assessment and treatment of anxiety and mood disorders, with the aim of refining differential diagnosis as well as cognitive behavioral interventions for cases across the affective disorders. She concluded her doctoral training with a twelve-month clinical internship emphasizing anxiety and traumatic stress at the Medical University of South Carolina.