SELECTIVE ATTENTION AND WORKING MEMORY MAINTENANCE FOR THREATENING FACES IN SOCIAL ANXIETY: AN ERP STUDY

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Abstract: Social anxiety disorder is a common syndrome characterized by excessive fear of negative evaluation in social situations. Cognitive theories (e.g., Clark & McManus, 2002; Heimberg, Brozovich, & Rapee, 2010) suggest that biases in attention play an important role in maintaining social fears. These models posit that socially anxious individuals focus attention on aspects of themselves (e.g., sensations of physiological arousal) and the social environment (e.g., potentially evaluative facial expressions) which indicate risk of negative appraisal by others. However, few studies have used lateralized event-related potentials (ERPs) to evaluate when these biases occur within stages of information processing. The goal of this study was to utilize ERPs (i.e., N2pc and CDA) during a change detection task in order to examine biases in selection (i.e., N2pc amplitude) and maintenance (i.e., CDA amplitude) of attention toward socially threatening faces in socially anxious subjects. Additionally, the effect of self-focused attention on these biases was examined using false heart rate feedback during the task. As hypothesized, socially anxious subjects showed early and sustained biased attention for disgust faces relative to neutral faces, and non-anxious controls did not show this bias. However, controls showed an early bias (N2pc) for disgust faces when heart rate cues were present, whereas socially anxious subjects showed no bias in this condition. Contrary to the hypotheses, controls showed an ipsilateral delay activity after being cued to attend to one hemifield, perhaps indicating active suppression of contralateral distractors. These findings and supplementary data are discussed in light of cognitive models of social anxiety disorder, recent empirical findings, and treatment.

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CHAPTER I

INTRODUCTION

Social anxiety disorder (SAD) is characterized by excessive fear of negative evaluation in social situations (APA, 2013). Cognitive models posit that social fears prompt biased attention toward fear-salient internal and external information (Clark & McManus, 2002; Clark & Wells, 1995; Heimberg, Brozovich, & Rapee, 2010; Rapee & Heimberg, 1997). These theories share the prediction that social anxiety is maintained by cognitive biases which serve as core components in dysfunctional thought processes (see Amir & Foa, 2001; Heinrichs & Hofmann, 2001). Attentional biases are particularly important to these models, which generally describe two types: 1) internal self-focused attention and 2) external attention to cues that one may be evaluated negatively, including early (i.e., vigilance) and late processes (i.e., difficulty disengaging attention and attentional avoidance). Internal and external signals that may be sources of social threat are thought to be prioritized by selective attention and maintained in working memory. Furthermore, cognitive theories assert that these biases reduce the availability of attention for successfully navigating the social environment. This interference is thought to confirm the socially anxious person’s fear, thereby maintaining it and prompting maladaptive cognition in future social situations.

Several theoretical discrepancies persist, and few data are available to address them. One distinction between these theories is that Clark (Clark & McManus, 2002; Clark & Wells, 1995) emphasizes the role that self-focused attention plays in reduced attention to social cues. Clark and McManus (2002) posit that biases in detecting social threat may only emerge if subjects are explicitly instructed to attend to social cues. Heimberg (Heimberg et al., 2010; Rapee & Heimberg, 1997) suggests that vigilance for potentially negative social cues is fundamental and that, in combination with self-focused attention, reduces available resources for successful social interaction. Additionally, the literature is replete with mixed findings in reaction time data regarding vigilance, with many studies suggesting attentional avoidance of negative social information. This has presented a challenge to theories for the better part of two decades. Research has attempted to clarify moderators which may explain discrepant observations, but these studies are limited by a reliance on reaction time (e.g., Judah, Grant, Lechner, & Mills, 2013) and/or eye tracking data (Schofield, Johnson, Inhoff, & Coles, 2012), neither of which measure attention directly. Thus, it is unclear to what extent discrepant findings may be the result of methodological limitations.

In order to advance these theories, researchers have recently drawn hypotheses from models of anxiety and attention, particularly attentional control theory (e.g., Amir & Bomyea, 2011; Judah, Grant, Lechner, & Mills, 2013; Judah, Grant, Mills, & Lechner, 2013; Wieser, Pauli, & Mühlberger, 2009). Attentional control theory (ACT) posits that anxiety is associated with increases in stimulus-driven attention, particularly toward threat, and reductions in goal-driven attention (Eysenck, Derakshan, Santos, & Calvo, 2007). Anxiety is thought to motivate greater effort toward tasks, resulting in maintained performance at the cost of efficiency, provided that cognitive systems are not overburdened. ACT dovetails nicely with cognitive theories of SAD and draws more specific predictions regarding stages of information processing. Past research has suggested that testing the predictions of such theories within the context of SAD may advance both theories (e.g., Judah, Grant, Lechner, & Mills, 2013; Judah, Grant, Mills, & Lechner, 2013).

Studies using event-related potentials, a non-invasive and direct measure of summated cortical post-synaptic potentials, may be particularly well-suited to resolving discrepancies in data regarding SAD. The temporal resolution of ERPs exceeds that of reaction time studies, which include noise from non-attentional processes. ERPs also provide a direct measure of covert attention processes without relying upon downstream behavioral measures. Thus, ERPs are well-suited to examine cognitive processes in social anxiety, and doing so has yielded interesting results. For example, Judah, Grant, Mills, and Lechner (2013) examined the CNV, a measure of cognitive resources deployed for response preparation, as subjects high and low in social anxiety prepared to look toward or away from stimuli. CNV amplitude was larger for socially anxious individuals compared to controls, but was significantly reduced for trials in which false heart rate feedback was presented. The authors interpreted this as evidence that the socially anxious group allocated more cognitive resources during response preparation, but when interoceptive threat was present, prompting self-focus, it distracted their attention from preparing a response.

The N2pc and contralateral delay activity (CDA), both laterally distributed posterior-occipital ERPs, are well-established as useful for examining selective attention and maintenance in working memory, respectively. Both ERPs are evident at scalp sites contralateral to the side of the visual field which is preferentially attended. The N2pc emerges about 200 ms after stimulus presentation, and the CDA emerges about 300 ms after a brief (e.g., 100 ms) stimulus presentation and persists as the stimulus is maintained in working memory (Luck & Hillyard, 1994; Vogel & Machizawa, 2004). The N2pc has been used to examine selective attention for objects appearing in one hemifield (i.e., side of the visual field) relative to those in the other (e.g., Weymar, Gerdes, Löw, Alpers, & Hamm, 2013), including facial expressions (Eimer & Kiss, 2007). The CDA has been used to examine biases in working memory maintenance (i.e., difficulty disengaging attention), including biases for fearful facial expressions in anxious individuals. For example, Stout, Shackman, and Lawson (2013) examined an unselected sample using a change detection task in which subjects detected changes in faces with neutral and fearful facial expressions. They found that trait anxiety predicted greater working memory storage of task-irrelevant fearful faces in working memory as indicated by the CDA. Thus, studies using the N2pc may be able to resolve questions regarding selective attention (i.e., vigilance) for social threat, and the CDA may be used to address questions about later attentional biases (i.e., avoidance and difficulty disengaging attention). Despite the advantages of the N2pc and CDA over other ERPs, including their unique suitability for evaluating the deployment of attention between objects concurrently within the visual field, a review of the literature suggested that researchers have not yet utilized either component to investigate attentional biases in social anxiety.

The present study drew its hypotheses from cognitive models of SAD, attentional control theory, and previous research. The primary goal was to examine whether socially anxious individuals display biased selection and storage in working memory for socially threatening faces. A secondary goal was to examine the influence of self-focused attention on these biases. This was examined using a modified change detection task. Subjects viewed an array of four faces, two on each side of the visual field. Faces on one side displayed neutral expressions, and those on the other displayed disgust expressions. The array then disappeared, followed by a cue to attend to one side. Subjects then reported whether or not any of the faces had changed in a subsequent test array. Self-focused attention was manipulated for 50% of trials by providing a randomly appearing change in the fixation symbol, which participants were told beforehand would indicate elevated heart rate. The N2pc, event-locked to the presentation of a stimulus array, was used to examine biases in selection of disgust versus neutral faces. Two CDA waveforms were evaluated following the offset of the stimulus array in order to investigate biases in working memory with and without the presence of task demands. The CDA immediately after the offset of the stimulus array (i.e., uncued CDA) was used to examine biases in working memory without task demands. The CDA following the cue to attend to one side was used to evaluate filtering of task-irrelevant information, including threatening faces, from working memory (i.e., cued CDA).

It was hypothesized that socially anxious individuals would display biased selection of socially threatening facial expressions as indicated by larger N2pc amplitude for disgust faces compared to individuals low in social anxiety. Additionally, it was expected that the socially anxious group would show biased maintenance of threatening material (i.e., disgust faces) in working memory as reflected by larger amplitude of the uncued CDA compared to the control group. It was hypothesized that this effect would persist in the cued CDA, suggesting maintenance of threatening task-irrelevant material in working memory for socially anxious subjects. Specifically, cued CDA amplitude was expected to be larger for socially anxious subjects when prompted to attend to disgust faces and smaller when prompted to attend to neutral faces compared to controls. Lastly, it was hypothesized that the presence of false feedback that the subject's heart rate had accelerated would enhance these effects. This is in line with theories which posit that self-focus increases the salience of external evaluative information and data which suggest that simultaneous cognitive processes may reduce the ability to effortfully direct attention away from threat (Cisler & Koster, 2010; Judah, Grant, Mills, & Lechner, 2013; Rapee & Heimberg, 1997). However, some theoretical perspectives (e.g., Clark & Wells, 1995) alternatively predict that self-focus should result in reduced attention toward external stimuli, including socially threatening faces.

CHAPTER II

REVIEW OF THE LITERATURE

Social anxiety disorder (SAD) is among the most common of the anxiety disorders with a lifetime prevalence of 10-13% (APA, 2013; Kessler et al., 2005). SAD interferes with educational and occupational functioning and is associated with financial difficulties and lower socioeconomic status (Brown, Heimberg, & Juster, 1995; Heimberg et al., 1990; Katzelnick et al., 2001; Lipsitz & Schneier, 2000). Furthermore, individuals with SAD are at increased risk for major depressive disorder (Grant, Beck, Farrow, & Davila, 2007; Grant et al., 2014), alcohol and substance abuse (Buckner et al., 2008; Morris, Stewart, & Ham, 2005), suicidal ideation (Davidson, Wingate, Grant, Judah, & Mills, 2011) and, in cases of comorbid depression, suicide attempts (Schneier, Johnson, Hornig, Liebowitz, & Weissman, 1992). The disorder tends to take a chronic course typically lasting a median of 25 years (DeWit, Ogborne, Offord, & MacDonald, 1999).

Theories of Social Anxiety Disorder

Various theoretical perspectives have contributed to the conceptualization of SAD. Interpersonal theories of SAD (e.g., Alden, 2001; Alden & Taylor, 2004; 2010) posit that individuals with SAD engage in social behaviors aimed toward two conflicting goals: 1) to achieve closeness with others and 2) to avoid negative evaluation. Social fears are learned via these strategic interpersonal behaviors (e.g., minimal self-disclosure). However, these behaviors are actually socially maladaptive and elicit reactions from others which confirm social fears, a process which results in distorted relational schemas (Alden & Phillips, 1990; Alden & Taylor, 2010). These schemas are the basis for future expectations about social situations and prompt greater fear. Thus, the process is a maladaptive feedback loop. Research generally supports this theoretical perspective (e.g., Davila & Beck, 2002; Grant, Beck, Farrow, & Davila, 2007, Grant et al., 2014; Tucker et al., 2013). For example, Tucker and colleagues (2013) found that the use of self-defeating humor, characterized by public self-deprecation, moderated the relationship between social anxiety and depression such that it was stronger for individuals who used this type of humor. Davila and Beck (2002) found that social anxiety predicted a variety of dysfunctional interpersonal styles, including poor assertiveness and overreliance upon others, both of which mediated the relationship between social anxiety and interpersonal stress. In a prospective study using structural equation modeling, Grant, Beck, Farrow, & Davila (2007) found that social anxiety was associated with low assertiveness, interpersonal dependency, and avoidance of emotional expression, the last of which also predicted depressive symptoms one year later. Such research has increased our understanding of how SAD develops as well as factors which affect its course and risk for other negative outcomes.

With the advent of neuroimaging and gene-sequencing techniques, neurobiological theories have begun to contribute to knowledge about SAD and to confirm the predictions of cognitive theories (see Freitas-Ferrari et al., 2010 for a review). These models typically build upon existing frameworks describing how localized neurochemistry and connectivity among brain regions are involved in emotion and cognition. The corticolimbic (also known as the limbic-cortical) model is pre-eminent among these theories. As alluded to by its name, this theory focuses on the role of aberrant functioning of corticolimbic areas and the connections between them. The amygdala is one important limbic structure which plays a basic role in emotional processing and has been particularly implicated in fear and anxiety. For example, studies examining animal models undergoing fear conditioning have shown increased amygdala reactivity to the conditioned stimulus (see Pine, 2001 for a review). Amygdala lesions in macaques have resulted in disinhibition of social behaviors and approach toward novel objects (Amaral, 2002). Humans have shown enhanced amygdala reactivity when viewing negative emotional images (Shah, Klumpp, Angstadt, Nathan, & Phan, 2009). For individuals with SAD, enhanced amygdala activity has been observed when exposed to social threat cues (Furmark et al., 2002, 2004; Tillfors et al., 2001; Tillfors, Furmark, Marteinsdottir, & Fredrikson, 2002) and threatening facial expressions (i.e., angry, contemptuous, disgusted, and fearful faces; Phan et al., 2006; Stein, Goldin, Sareen, Zorrilla, & Brown, 2002). Furthermore, research suggests that there is an association between this reactivity and symptom severity (Phan, Fitzgerald, Nathan, & Tancer, 2006). Even eye contact can result in amygdala reactivity for individuals with SAD (Schneier, Kent, Star, & Hirsch, 2009). Following successful treatment of SAD, individuals show reduced amygdala response to social threat (Furmark et al., 2002; 2005; 2008).

The hippocampus is a critical part of the corticolimbic model. Its coordination with the amygdala has presented a challenge to investigations of the hippocampus' role in social anxiety disorder. Extant data suggest that the hippocampus is involved in evaluating potentially threatening information, a function which fits neatly with cognitive models (see Freitas-Ferrari, et al., 2010). Studies observing dysfunction in this region have linked it with generalization of threatening stimuli and related anxiety (Cannistraro & Rauch, 2003; Freitas-Ferrari, et al., 2010). In support of the corticolimbic model, research suggests that cortical areas receiving hippocampal projections (e.g., the parahippocampal gyrii) are activated when social phobics view social-evaluative faces (Goldin, Manber, Hakimi, Canli, & Gross, 2009).

Several other cortical areas have been implicated in SAD, including the insula, medial prefrontal cortex (mPFC), and anterior cingulate cortex (ACC), a region which overlaps with mPFC. The insula is involved in interoceptive and pain awareness (Freitas-Ferrari, et al., 2010). Studies have noted insula hyperactivation when socially anxious individuals view faces with direct eye contact (Schneier, et al., 2009). This is consistent with the prediction of cognitive models that socially anxious individuals have increased self-focus in threatening social situations, including forming third-person images of the self as others may see it (Clark & Wells, 1995; Rapee & Heimberg, 1997). The mPFC has been observed to be involved in anticipatory processing (Tillfors et al., 2002). GABAergic neurons in the medial prefrontal cortical area in general are thought to downregulate the amygdala (Freitas-Ferrari, et al., 2010), indicating an important relationship typical of the interactive functioning that the corticolimbic model proposes. Abnormalities in the insula and mPFC have been observed to attenuate with successful treatment (Warwick, et al., 2010).

The ACC, a structure which mediates prefrontal cortex and structures in the limbic system, appears to be an integral part of the corticolimbic theory. In individuals with SAD the ACC reacts to faces displaying disgust, and this activity is associated with faster recognition of disgust and more negative evaluations of neutral faces (Amir, et al., 2005). Like the insula, the ACC reacts to direct eye gaze (Schneier, et al., 2009), perhaps as it attempts to categorize this innocuous cue as threatening or neutral and recruit cortical resources for an appropriate response. For this reason, it has been suggested that the hyperactivity of certain regions of the ACC in social anxiety is related to disinhibition of response to negative emotional stimuli (Amir, et al., 2005). Yet, as with any neural structure, sub-regions may function differently. The dorsal region of the ACC, for example, has been shown to recruit the dorsolateral PFC to regulate the limbic system and control attention (Freitas-Ferrari, et al., 2010; Kerns et al., 2004). In contrast the subgenual ACC, which has extensive limbic connectivity, including extensive connections to the amygdala, is active during the processing of harsh facial expressions, particularly when socially anxious individuals are not engaging in emotion regulation (Goldin, et al., 2009). More distal cortical regions involved in visual attention also have been identified as important neural correlates of SAD. These include the fusiform face area and the inferior occipital gyrus, which are hyperactive when socially anxious individuals view threatening faces (Goldin, et al., 2009).

In addition to the neuroanatomical correlates of SAD, neurochemicals, particularly serotonin, and their regulators have been implicated in the disorder. Serotonin transporters, presynaptic proteins responsible for reuptake of serotonin from the synaptic cleft, are one key regulator of serotonin in the brain (Lesch et al., 1996). Expression of the serotonin transporter gene (*SLC6A4*) is modulated by gene variants, including those in the *SLC6A4*-linked polymorphism in the promoter region of the gene (*5-HTTLPR*; see Canli & Lesch, 2007). This polymorphism is of particular interest because of research which implicates its role in SAD (Furmark et al., 2004; 2009), attentional biases (Beevers, Ellis, Wells, & McGeary, 2010; Beevers, Gibb, McGeary, & Miller, 2007; Beevers, Wells, Ellis, & McGeary, 2009; Fox, Ridgewell, & Ashwin, 2009), activity in brain areas implicated in SAD (Canli et al., 2005; Furmark et al., 2004; 2009; Graff-Guerrero et al., 2005; Hariri et al., 2005), and treatment response in SAD (Stein, Seedat, & Gelernter, 2006). It is important to note that research implicates the polymorphism in a variety of anxiety and mood disorders, particularly major depressive disorder, rather than SAD in particular (see Canli & Lesch, 2007). Generally, the literature suggests that short alleles of the polymorphism are associated with dysfunction, although there are exceptions which implicate long alleles (e.g., Arbelle et al., 2003). Short alleles of the serotonin transporter gene have been found to be associated with blushing in subjects with SAD (Domschke, et al., 2009). Moreover, diminished grey matter in the ACC and amygdala has been identified in homozygous carriers of the short allele (Pezawas, et al., 2005). In a series of studies, Furmark and colleagues (2004) found that short alleles predicted greater symptom severity and amygdala reactivity in social phobics and that possessing one, or especially two, short alleles predicted amygdala reactivity to angry faces for both socially anxious and healthy control subjects (Furmark et al., 2009). Homozygous carriers of the long allele have been found to show greater selective attention for positive stimuli and avoidance of negative stimuli (Fox et al., 2009), and this finding has been replicated using emotional faces (Pérez-Edgar et al., 2010). Similarly, other studies have suggested that short allele carriers display difficulty disengaging attention from emotional stimuli, including happy, sad, and fearful images (Beevers et al., 2009). In a follow-up study using eye tracking, these researchers found that homozygous carriers of the short allele displayed longer fixation of eye gaze for positive images compared to carriers of at least one long allele (Beevers et al., 2010). Together, these studies suggest a possible neurocognitive endophenotype which conveys vulnerability to anxiety and mood pathology, although more research is needed, particularly studies which investigate gene-environment interactions.

Cognitive Models

Cognitive theories of SAD (Clark & Wells, 1995; Clark & McManus, 2002; Heimberg et al., 2010; Rapee & Heimberg, 1997) have been particularly influential in research spanning the last two decades. These models are characterized by a focus on the role of information-processing (i.e., attention, interpretation, and memory) and elaborative thought processes in the development and maintenance of symptoms. As with other cognitive theories of psychopathology, these theories posit that maladaptive beliefs about the self and others are fundamental to the disorder. For example, socially anxious individuals may believe that they are unlikeable, awkward, unintelligent, or in other ways lack qualities which they believe are necessary to be accepted by others. The ambiguity of social situations presents opportunities for negatively biased cognitive processes. The resulting experience of such situations as threatening reaffirms dysfunctional beliefs and perpetuates social fears, a process which becomes a vicious cycle (Clark & McManus, 2002; Clark & Wells, 1995; Rapee & Heimberg, 1997).

According to cognitive models, a variety of maladaptive processes are fundamental to SAD. Clark and Wells (1995) suggested that these dysfunctional cognitions occur before, during, and after social interactions. Before these situations, individuals engage in anticipatory processing, a repetitive negative thinking style in which one imagines herself/himself in an upcoming social situation. In the midst of social situations, individuals imagine themselves as a social object from a third-person perspective. They experience increases in self-focused attention and vigilance for cues which might indicate negative evaluation. Aspects of the situation are interpreted in a negatively biased way. After the social situation, socially anxious individuals engage in post-event processing, a ruminative focus on aspects of the social situation which were perceived to be negative (Clark & Wells, 1995; Rapee & Heimberg, 1997).

One important aspect of cognitive models is that they propose mechanisms whereby cognitive processes maintain anxiety. Rapee and Heimberg (1997) suggested that the automatic allocation of attention toward self and threat in the environment reduces the availability of cognitive resources which might otherwise be employed toward successful social behaviors. They labeled this the “multiple task paradigm” and suggested that one level of interference occurs simply because there are additional and unnecessary cognitive processes at work in social situations. For example, attention toward one’s physiological anxiety symptoms may distract them from detecting subtle social cues, resulting in socially inappropriate behavior. Additionally, cognitive biases may prevent the detection or accurate processing of positive social feedback. Biased attention and interpretation regarding aspects of the self and environment serves as evidence supporting the validity of social fears. This prompts socially anxious individuals to engage in safety behaviors, which are attempts to avoid or mitigate particularly threatening elements of the situation. For example, a socially anxious individual may frequently check a cellular phone or pretend to read and send texts in order to dampen the negative evaluation or awkwardness they fear will occur during conversations. Ironically, these behaviors may increase the likelihood that others will react in ways that are feared. Thus, cognitive models predict that dysfunctional cognitive processes are a key source of maladaptive social behaviors and that these thoughts and behaviors maintain social fears and may even contribute to feared outcomes.

Cognitive models of SAD describe processes which bear a close resemblance to constructs in the social psychology literature, such as anchoring and adjusting, the spotlight effect, and the illusion of transparency. Anchoring and adjusting refers to a heuristic used in ambiguous situations. The most conveniently available information is used as a starting point (anchoring) and is rectified afterward if other information is available (adjusting; see Tversky & Kahneman, 1974). This heuristic may play a role in the spotlight effect, a cognitive bias in which one overestimates how much they are the object of others' attention (Gilovich & Savitsky, 1999). Research suggests that this process is driven by anchoring to one's internal experience and failing to adjust, that is, to take into account that others' experiences may be different from one's own (Gilovich & Savitsky, 1999). The spotlight effect resembles self-focused attention as described by cognitive models of SAD (Clark & Wells, 1995; Rapee & Heimberg, 1997).

A concept closely related to the spotlight effect, the illusion of transparency, occurs when a person overestimates the extent to which his/her internal state is noticeable to others. Research suggests that this process is driven by emotional and physiological sensations of such an intensity that the person becomes keenly aware of them and believes they must also be noticeable to others (Chapman & Johnson, 2002; Epley & Gilovich, 2001; Gilovich, Savitsky, & Medvec, 1998; Gilovich & Savitsky, 1999). In the case of social anxiety, where such symptoms might lead to negative evaluation, it is not surprising that social fears and self-focus may exacerbate one another. Indeed, Savitsky and Gilovich (2003) observed the illusion of transparency in an unselected sample during a public speaking task and concluded that speech anxiety and the illusion of transparency were mutually increasing one another. A closely related phenomenon, the observer's illusion of transparency, describes an overestimation of one's ability to know what others are thinking and feeling. This resembles predictions in interpersonal and cognitive models of SAD which posit that socially anxious individuals assume that others are fundamentally judgmental, a belief which may be driven by anchoring to their own self-evaluation.

Support for Cognitive Models

Self-focused Attention (Internal Bias).

Evidence generally supports the predictions of cognitive models with regard to self-focus in SAD. Early investigations pre-dating the leading cognitive models relied on self-report measures assessing self-consciousness and found evidence of a relationship with social anxiety

(Bruch & Heimberg, 1994; Fenigstein, Scheier, & Buss, 1975; Hope, Heimberg, & Klein, 1990; Melchior & Cheek, 1990). Research has suggested that this self-focus was specific to public rather than private self-consciousness, which are distinguished by their observability to others (Hope & Heimberg, 1988). Following the advent of cognitive theories of SAD, researchers began to examine the specific predictions of these models. For example, Hackmann, Surawy, and Clark (1998) conducted semi-structured interviews with social phobics and healthy controls. They found that the SAD group reported a higher rate (77%) than controls (10%) of intrusive imagery of how they appeared to others from a third-person point of view.

Researchers also have investigated the role of interoceptive preoccupation in self-focused attention. The association between physiological arousal and increased self-focus/self-awareness has long been observed (Fenigstein & Carver, 1978; Scheier & Carver, 1983; Wegner, & Giuliano, 1980). Additionally, studies of anxiety sensitivity, the fear of physiological symptoms of anxiety and their potential negative consequences, suggest it is a common feature across the anxiety disorders (Domschke, Stevens, Pfleiderer, & Gerlach, 2010; Grant, Beck, & Davila, 2007; Naragon-Gainey, 2010; Taylor, Koch, & McNally, 1992). Along these lines, a recent study found that subjects with SAD reported greater anxiety and greater subjective intensity of somatic sensations during interoceptive exercises than did healthy controls (Collimore & Asmundson, 2013). Other research has found that individuals with SAD have greater anxiety about potential social consequences to their physiological symptoms, particularly negative evaluation (Carleton, Collimore, & Asmundson, 2010; Deacon & Abramowitz, 2006; Rector, Szacun-Shimizu, & Leybman, 2007; Rodriguez, Bruce, Pagano, Spencer, & Keller, 2004; Taylor et al., 2007). This research supports the hypothesis that attention toward physiological symptoms, particularly those associated with anxiety, may play a key role in self-focused attention.

Several studies have found evidence that individuals with SAD monitor their physiology, particularly their heart rate, which prompts the formation of negative self-images (Mansell, Clark, & Ehlers, 2003; Papageorgiou & Wells, 2002; Stevens et al., 2011; Wells, Clark, & Ahmad, 1998; Wells & Papageorgiou, 1999). Research also suggests that attention to somatic/physiological sensations is associated with more negatively biased beliefs about how one is being evaluated (Mansell & Clark, 1999; McEwan & Devins, 1983; Mellings & Alden, 2000; Woody, 1996). Gerlach, Mourlane, and Rist (2006) compared the anxiety levels of subjects with SAD and healthy controls while they listened to their own heart beat privately or before a group who also heard it. Subjects with SAD reported more anxiety than controls and increased anxiety and worry when heart beats were heard by others compared to the private condition, whereas the control group did not. Similarly, another study found that socially anxious children perceived false audible heart rate feedback to be faster compared to controls and that they were more worried when this feedback was public, but the control group was not (Schmitz, Blechert, Krämer, Asbrand, & Tuschen-Caffier, 2012). Such studies have advanced cognitive theories by specifying basic aspects of self-focused attention, specifically, that social phobics are anxious about how others may perceive somatic evidence of their anxiety. Some of this research went further by attempting to manipulate self-focused attention using pseudo heart rate feedback (e.g., Mansell et al., 2003; Papageorgiou & Wells, 2002), finding that this was associated with a disproportionately greater increase in self-focus and anxiety for socially anxious subjects compared to controls. Following this research, Judah, Grant, Mills, and Lechner (2013) examined the effect of false heart rate feedback on anxiety and attentional control in an antisaccade task. They found that, compared to non-anxious controls, socially anxious subjects reported greater increases in self-consciousness when cued that their heart rate was elevated. Additionally, they reported that the feedback caused greater interference with their task performance than did controls. Interestingly, Judah and colleagues also found that socially anxious subjects showed delayed onset of the P3b waveform, an ERP reflecting stimulus categorization, when heart rate feedback was present. This was interpreted as evidence that self-focused attention was interfering with cognitive efficiency. Moreover, socially anxious individuals showed greater CNV amplitude prior to saccades than controls, suggesting greater effort. However, this was reduced for the socially anxious group for trials on which heart rate feedback was provided, suggesting that self-focused attention was interfering with the deployment of attention in preparation for making task-relevant responses. These results suggested that self-focused attention, particularly cues of physiological arousal (e.g., accelerated heart rate), interfere with cognitive processes in socially anxious individuals.

Other recent studies have examined the relationship between self-focused attention and anticipatory processing. Mills, Grant, Judah, and Lechner (2014) assigned undergraduates who were low or high in social anxiety to engage in approximately five minutes of anticipatory processing or distraction after being told that they would engage in a subsequent social interaction. They found that HSAs in the anticipation condition reported more self-focus than those in the distraction condition. This self-focus also mediated the relationship between social anxiety group and interpretation biases. In a follow-up study, Mills, Grant, Judah, and White (2014) examined the effect of this anticipatory processing manipulation on internal and external attentional biases in socially anxious and non-anxious participants. Self-focused attention was assessed using a dot-probe task in which pictures of heart rate waveforms and sound waves were presented on opposite sides of the screen. Participants were misled to believe that the heart rate waveforms were snapshots of their own heart rate. Mills and colleagues found that socially anxious subjects in the anticipation condition showed a large increase in self-focused attention as measured by bias change scores. Both of these studies provide support for the prediction that anticipatory processing increases self-focus, and these findings support and advance cognitive theories of SAD.

External Biases.

Empirical findings regarding biases in external attention are less clear than those for self-focused attention. Broadly, studies support preferential detection of socially threatening material in social anxiety, a process often labeled “vigilance” (see Cisler & Koster, 2010). However, much of the literature has been unable to clarify the time course of attentional biases, particularly how attention is deployed at later stages. This literature is strengthened by use of a variety of paradigms, including emotional Stroop, dot-probe, and visual search tasks, as well as various outcome measures, including reaction time, performance, and eye tracking.

The emotional Stroop task (see Williams, Mathews, & MacLeod, 1996 for a review) was one of the earliest tasks that assessed attentional biases by measuring interference with processing task-relevant features of stimuli. The task was adapted from Stroop's (1935) original design, which requires participants to name the color of various color-words (e.g., "red") which are congruent or incongruent with the color of the word. Incongruent trials typically result in slower reaction times than congruent trials, suggesting that processing of task-irrelevant stimulus features interferes with the task. Researchers have noted similar results when using threat words. Slowed reaction times are evident in individuals with SAD (Amir et al., 1996; Amir, Freshman, & Foa, 2002; Hope, Rapee, Heimberg, & Dombeck, 1990; Lundh & Öst, 1996; Maidenberg, Chen, Craske, Bohn, & Bystritsky,1996; Mattia, Heimberg, & Hope, 1993; McNeil et al., 1995) and socially anxious individuals (Grant & Beck, 2006) when identifying the color of social threat words. Lundh and Öst (1996) found that subjects with SAD did not differ from healthy controls in Stroop effects for color or general threat. Thus, research using the emotional Stroop task generally has supported predictions of cognitive models of SAD.

The dot-probe task (also known as the visual probe or probe detection task) is among the most commonly used paradigms for investigating attentional biases in SAD. First introduced by MacLeod, Mathews, and Tata (1986), this task evaluates the costs of biased attention on probe detection. Typically, a pair of pictures appears simultaneously on each side of (alternatively, above and below) a centrally located fixation cross. The stimuli disappear, and a probe is presented immediately in the location of one of the stimuli. Participants must identify the position of the probe. If an attentional bias toward one of the stimuli is present, this is likely to lead to the preferential deployment of attention toward one stimulus so that detection of the probes that replace that type of stimulus will be speeded relative to probes which replace the other stimulus type. Various versions of the task have been developed which compare more than two stimuli, require probe identification (e.g., "E" or "F"), or present stimuli at varying stimulus onset asynchronies (SOAs). In the social anxiety literature, the dot-probe task commonly utilizes pairs of socially threatening and neutral words or facial expressions. Bias scores are calculated by subtracting mean reaction times to probes replacing emotional stimuli from mean reaction times to probes replacing neutral stimuli (e.g., Judah, Grant, Lechner, & Mills., 2013). Overall, dot-probe studies examining clinical samples using short SOAs (i.e., < 500 ms) have supported Rapee and Heimberg's (1997) prediction that socially anxious individuals show preferential detection of environmental cues which indicate potential social threat (Asmundson & Stein, 1994; Mogg, Philippot, & Bradley, 2004; Mueller et al., 2009; Musa, Lépine, Clark, Mansell, & Ehlers, 2003; Sposari & Rapee, 2007). Results have been similar in studies comparing groups high and low in social anxiety without assessing diagnostic status (e.g., Klumpp & Amir, 2009; Mogg & Bradley, 2002; Vassilopoulos, 2005). However, there are notable exceptions which fail to support attentional bias toward threat (e.g., Horenstein & Segui, 1997; Pineles & Mineka, 2005).

Visual search tasks represent another paradigm which assesses attentional biases via reaction time costs. This task requires participants to locate a target within a field of distractors. Few studies have used this approach to examine social anxiety, yet those that have done so support cognitive models. For example, a study using the face-in-the crowd paradigm (i.e., visual search task using faces) found that subjects with SAD, but not healthy controls, showed attentional biases for angry compared to happy faces (Gilboa-Schechtman, Foa, & Amir, 1999). This finding was replicated in a similar study using schematic facial expressions (Juth, Lundqvist, Karlsson, & Öhman, 2005).

Eye tracking has several advantages over reaction time tasks. Unlike the dot-probe task, which provides only a snapshot of attentional deployment, eye tracking can assess the deployment of attention using numerous parameters, such as duration of fixation and onset of saccadic movements. Eye positions also represent a more direct measure of overt attention than reaction time (Duchowski, 2007, pp. 209). Nevertheless, there are limitations to the inferences that can be drawn about attention using eye tracking. Helmholz (1962) first demonstrated that attention could be directed effortfully toward stimuli in the parafoveal and peripheral parts of the visual field. For the socially anxious person, eye-gaze may constitute a social behavior that could elicit evaluation from others. Thus, these individuals may be motivated to mask the focus of their attention by not looking at it directly or doing so only briefly.

Importantly, eye tracking has been combined with other paradigms, such as dot-probe tasks, in order to overcome the limitations of each approach. For example, Schofield and colleagues (2012) used eye tracking in a dot-probe task and found evidence suggesting that socially anxious individuals display biased attention, as indicated by longer dwell times, toward emotional faces throughout a 1500 ms stimulus presentation. In contrast to this, a similar study found attentional bias toward emotional faces during the first second of presentation, but avoidance of emotional faces from 1000 to 1500 ms (Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009). This discrepancy is characteristic of mixed findings regarding late attentional biases, as is described more fully below. Such discrepancies may be due to limitations associated with particular paradigms. Because the dot-probe task presents an unrealistic scenario which encourages attention to be deployed toward one of two stimuli, Horley and colleagues (2003; 2004) conducted two studies using eye tracking while presenting single images depicting emotional facial expressions to subjects with SAD and healthy controls. In both studies the clinical group displayed less dwell time on facial features, particularly the eyes and mouth, compared to controls. Such studies exemplify the important contributions that eye tracking has made to understanding attentional biases in SAD.

Several studies have utilized event-related potentials to investigate attentional biases in social anxiety (Judah, Grant, Mills, & Lechner, 2013; Kolassa et al., 2009; Kolassa, Kolassa, Musial, & Miltner, 2007; Kolassa & Miltner, 2006; Moser, Huppert, Duval, & Simons, 2008; Mueller et al., 2009; Peschard, Philippot, Joassin, & Rossignol, 2013; Rossignol, Anselme, Vermeulen, Philippot, & Campanella, 2007). For example, Moser and colleagues (2008) examined ERPs as subjects high and low in social anxiety completed a modified version of the Erikson flanker task using positive and threatening facial expressions. This task includes a target with a series of peripheral stimuli which are congruent or incongruent with the central target, which the subject must identify. The late positive potential (LPP) waveform, a measure of emotional processing of stimuli, was larger for socially anxious subjects, but not controls, when viewing threatening face targets compared to positive targets, suggesting greater attention toward threat. Mueller and colleagues (2009) examined ERPs in socially anxious and control subjects who completed a dot-probe task using emotional facial expressions. Socially anxious subjects displayed smaller P1 amplitude, reflecting reduced spatial attention for that area (see Luck et al., 1994), for face pairs which contained a happy face compared to those which contained a negative (angry) facial expression. The authors interpreted this as evidence supporting vigilance for threat. P1 amplitudes for probes replacing neutral faces were larger compared to probes replacing emotional faces, a finding which suggests deployment of attention toward these locations in preference to those which contained threatening information. Another study examined subjects high and low in social anxiety as they viewed emotional facial expressions in an oddball paradigm and found that socially anxious subjects displayed a reduced N2b when detecting changes in the intensity of angry faces (Rossignol et al., 2007). Additionally, they found that socially anxious subjects showed delayed ERPs related to the categorization of angry faces which followed disgust faces, a pattern not present when this order was reversed or in control subjects under either condition. The authors interpreted this as evidence of the involuntary persistence of disgust faces in working memory. Although ERPs represent an important tool for testing cognitive models, the extant literature has several limitations, including studies which report substandard methodology (e.g., poor control of event timing, high impedances, over-filtering) and/or utilize components and paradigms which achieve ambiguous results.

Although extensive evidence supports attentional bias toward threat in studies using socially threatening words (Amir & Bomyea, 2011; Asmundson & Stein, 1994; Grant & Beck, 2006; Hope, Rapee, Heimberg, & Dombeck, 1990; Maidenberg et al., 1996; Mattia et al., 1993; McNeil, et al., 1995; Pishyar, Harris, & Menzies, 2004; Vassilopoulos, 2005) and faces (Garner, Mogg, & Bradley, 2006; Judah, Grant, Lechner, & Mills, 2013; Juth et al., 2005, study 4; Kolassa et al., 2007; Kolassa & Miltner, 2006; Mogg & Bradley, 2002; Mogg et al., 2004; Mühlberger, Wieser, Herrmann, Weyers, Tröger, & Pauli, 2009; Pishyar et al., 2004; Schofield et al., 2012; Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009), many studies have achieved discrepant results with regard to late attentional biases. Several studies suggest that social anxiety is associated with attentional avoidance at later stages (the vigilance-avoidance hypothesis; Mogg et al., 2004; Mueller et al., 2009; Pishyar et al., 2004; Vassilopoulos, 2005; Wieser, Pauli, Weyers, Alpers, & Mühlberger, 2009), and several other studies report an opposite pattern of findings, that socially anxious individuals show difficulty disengaging attention from social threat (Amir, Elias, Klumpp, & Przeworski, 2003; Buckner, Maner, & Schmidt, 2010; Moriya & Tanno, 2010; 2011; Schofield et al., 2012).

One of the more promising hypotheses for resolving the avoidance/difficulty disengaging controversy has been the examination of attentional control as a moderator. Cisler and Koster (2010) suggested that attentional avoidance may be effortful and therefore dependent on the availability of cognitive resources (i.e., working memory). In order to test this hypothesis, Judah, Grant, Lechner, and Mills (2013) modified a dot-probe task with emotional faces, a classic paradigm in this literature, to include a concurrent *n*-back task. The *n*-back task presented random cues prompting subjects to verbally identify the probe which appeared one (i.e., 1-back) or two (i.e., 2-back) trials previously. Stimuli were presented for 1500 ms in order to assess late attentional biases. Participants completed a standard dot-probe task as well as blocks with low (i.e., 1-back) and high (i.e,. 2-back) working memory load. The results suggested that socially anxious subjects showed avoidance of disgust faces when working memory load was absent or low (i.e., 1-back). However, subjects showed attentional biases toward (i.e., difficulty disengaging attention) these faces when working memory load was high (i.e., 2-back). The authors interpreted these findings as supportive of Cisler and Koster's hypothesis that the availability of working memory resources plays an important role in determining whether socially anxious subjects show avoidance or difficulty disengaging attention from threat. Findings from similar studies also lend support to this hypothesis (e.g., Derrybery & Reed, 2002; Ladouceur et al., 2009). For example, Derryberry and Reed (2002) found that attentional control moderated attentional biases in a sample high in trait anxiety. Subjects high in attentional control showed avoidance of threatening stimuli, whereas subjects low in attentional control displayed difficulty disengaging attention. Similarly, Ladouceur and colleagues (2009) found that high trait anxiety was associated with slowed reaction times for threatening stimuli during the high load (i.e., 2-back) condition of an emotional *n*-back task.

Although this study (i.e., Judah, Grant, Lechner, & Mills, 2013) may contribute toward understanding the time course of attentional biases in social anxiety, its results have several limitations. First, the dot-probe task provides only a snapshot of attention. Second, being a reaction time task, it is an indirect measure of attentional processes. Third, it is unclear why working memory load would vary among extant studies to produce the mixed results. Thus, the role of working memory load as a moderator of late attentional biases may lack explanatory power for discrepant findings regarding late attentional biases. Therefore, more research is needed which 1) assesses attentional biases with greater temporal precision, 2) uses direct measures of attentional deployment (e.g., ERPs), and 3) examines processes in social anxiety which may result in working memory load and thereby moderate attentional biases. With regard to this last point, self-focused attention in socially anxious individuals appears to preoccupy working memory resources and interfere with executive function. As noted earlier, Judah, Grant, Mills, and Lechner (2013) found that false heart rate feedback affected socially anxious subjects by reducing task-related attention, as indicated by an attenuated CNV, and by delaying categorization of instructional cues, as reflected in later P3b latency. This evidence supports cognitive theories, which posit that self-focused attention interferes with attention toward information in the environment, by suggesting that self-focus can impair attentional control. These data also suggest that examining working memory may be important for research investigating attentional biases.

Theories of Working Memory

The concept of working memory can be traced back to William James (1890) who described what he called “primary memory” as “the trailing edge of consciousness.” Theories of working memory necessarily posit that memory consists of multiple components. As described by Baddeley (2007), working memory theories have been challenged by single component models for much of the last century. Such models aimed to parsimoniously explain memory using learning theory (see McGeoch & Irion, 1952). Their influence was upheld by studies which suggested that decays in memory at short intervals were paralleled by decays in longer-term storage (e.g., Melton, 1962). Nevertheless, multi-component models occasionally surfaced, as in the case of Hebb’s (1949) hypothesis that transient neural activity was responsible for short-term memory and that enduring changes in the brain explained long term memory.

During the 1960s, cognitive psychology gave rise to information-processing models of memory (e.g., Atkinson & Shiffrin, 1968; Broadbent, 1958). Baddeley (2007) describes how this resulted in several revolutionary changes to the science of memory. First, memory processes were conceptualized as distinct stages, including storage, encoding, and retrieval. This enabled theorists to describe aspects of memory with greater precision and thereby produce more reliable models. Second, the two system framework was salvaged, partly due to its explanatory power for observations concerning memory systems. Third, novel experimental approaches in cognitive psychology improved the testability of models. This gave theoreticians both the motivation and the means to create more detailed models of memory (Tulving, 1979). During this time, Waugh and Norman (1965) revived Hebb’s (1949) distinction between short-term and long-term memory. Neuropsychological research, such as studies of patients with long-term but not short-term memory losses, and vice versa, provided support for this (e.g., Milner, 1966; Shallice & Warrington, 1970). Observations confirming that deficits could be isolated to one system with little or no effect in other memory systems served as a compelling argument for their theoretical distinction (Baddeley, 2007).

Thus, acceptance of the two-component model of memory increased. One popular theory was that of Atkinson and Shiffrin (1968), which was known as the modal model, alternatively, the information-processing model. The advent of the modal model provided a basis upon which to conceptualize working memory as a distinct function of memory. Thus, it is not surprising that working memory research advanced substantially in its wake. The modal model hypothesized that a short-term storage component, identified with working memory, mediated sensory processes and long-term memory. Each component of memory, such as perception, the short-term store, and the long-term store, was conceptualized as a gate in a series through which information must pass in order to be represented in the next stage of information processing. The modal model has been criticized for lacking mechanisms to explain certain observations, such as why information in the short-term store is not necessarily passed to long-term memory as a function of storage duration (e.g., Craik & Watkins, 1973, see also, Craik, Routh, & Broadbent, 1983). The model also struggles to explain why disruption of early stages, such as short-term memory, can have little effect on subsequent functions, such as long-term memory (Baddeley, 2007).

Baddeley's Model.

Baddeley and Hitch (1974) proposed a new model (sometimes referred to as the Multicomponent Model) in place of short-term memory in the multi-store model. Now most closely associated with Baddeley (1974, 2001, 2003, 2007, 2010), this model distinguishes working memory from short-term memory and long-term memory by noting its reliance on conscious effort in order to hold an object in active storage (Engle, Tuholski, Laughlin, & Conway, 1999). Baddeley has described four components to the model, three which store information and one which executes conscious control of the other systems (i.e., the central executive). The first storage system, the phonological loop, is a store for verbal-linguistic information. The second is the visuospatial sketchpad, a parallel storage system which handles mental images and spatial information. The central executive is described as a relay station executing control over the flow of information in and out of the other systems (Barrett, Tugade, & Engle, 2004). Later modifications of the model included a fourth subsystem, the episodic buffer, which stores integrated visual and verbal information (Baddeley, 2010).

Research supporting the distinction between the domain specific components, the phonological loop and the visuospatial sketchpad, has consistently found that material stored within one component competes with the storage of other material within it, but minimally interferes with information stored in the other (e.g., Alloway, Pickering, & Gathercole, 2006; Gruber & von Carmon, 2003). For example, one study investigated neural activity during an item recognition task with verbal or visuospatial rehearsal conditions (Gruber & von Cramon, 2003). These tasks also were administered with and without a secondary task in which subjects engaged in articulatory or visuospatial suppression. Differential patterns of activation supported the distinction between the verbal and visuospatial components of working memory. Similarly, researchers have suggested that the phonological and visuospatial components themselves may comprise multiple functions. Logie's (1995) research examining the visuospatial sketchpad noted relatively independent functions for storing the visuospatial features. The visual cache stores information about form, color, and other static features, whereas spatial orientation is processed by a component known as the inner scribe. Research tasks using dual-tasks within only one of these components reveal greater competition than dual-tasks which use both (Klauer & Zhao, 2004). Brain-imaging research provides additional support for the distinction between these components by suggesting that they utilize different areas of the brain (e.g., Gruber & von Cramon, 2003; Smith & Jonides, 1997).

Several researchers have examined the functions of the central executive (e.g., Smith & Jonides, 1999; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Miyake and colleagues (2000; Friedman & Miyake, 2004) used latent variable analysis to identify three functions of the central executive: inhibition of pre-potent actions, shifting attentional resources between tasks, and updating information in working memory. Posner's programmatic research of the executive function in visual attention identified distinct neural regions responsible for disengaging attention from an object and controlling voluntary eye movements (Posner & Fan, 2004; Posner & Raichle, 1994). Such studies have clarified the role of working memory in effortful behaviors which may be important for understanding attentional biases in SAD.

Anxiety and Working Memory.

Several theories have emerged to explain the relationship between anxiety and working memory (e.g., Easterbrook, 1959; Eysenck & Calvo, 1992; Eysenck et al., 2007; Sarason, 1988). These models share a basis in the Yerkes-Dodson Law (1908), which posits a quadratic relationship between arousal and performance such that performance is optimal at moderate levels of arousal. Although this observation does not explicitly reference memory or attention, its predictions were incorporated by later theorists who applied it to working memory. Easterbrook's cue utilization hypothesis (1959) was among the earliest and most basic attempts to describe how anxiety affects attention. Easterbrook proposed that anxiety/arousal reduces the ability to attend to environmental cues. Easterbrook's hypothesis preceded extant working memory models, yet it utilized observations of working memory's limited capacity to parsimoniously explain how anxiety can interfere with attention.

Cognitive interference theory (Sarason, 1988) extended Easterbrook's model. This model asserted that interference of anxious arousal with performance occurs via increases in self-preoccupation, which consumes limited working memory resources so that they are offline for other tasks which might otherwise use them. Thus, Sarason proposed that anxiety-driven cognitions and related working memory deficits are responsible for performance deficits related to anxiety. Cognitive interference theory describes three stages at which anxiety interferes with working memory: attention to the environment, information processing, and planning behaviors. Although its core predictions have held over time, cognitive interference theory has ceded its influence to more recent models which utilize more advanced theories of working memory (Eysenck, 2010).

Building upon cognitive interference theory, the processing efficiency theory (PET; Eysenck & Calvo, 1992) was the first model to incorporate Baddeley's model of working memory. It distinguished between processing efficiency, the cognitive resources utilized for a set level of performance, and effectiveness, the accomplishment of task goals. PET stated that worry and other cognitions related to anxiety preoccupy the phonological loop, which reduces its capacity for other processes. PET also predicted that effectiveness would suffer if the demands upon the phonological loop surpass the capacity necessary to maintain performance.

As Baddeley's theory garnered more support, research findings suggested the need for revisions to PET. Attentional control theory (ACT; Eysenck et al, 2007) discarded the hypothesis that worry interferes with the phonological loop. Instead, ACT proposed that anxiety disrupts the central executive. ACT posited that anxiety increases stimulus-driven attention at the cost of goal-oriented attention. In other words, resources are dedicated toward threat detection so that they are less available for controlling attention. PET's predictions regarding processing efficiency and effectiveness were retained in ACT. This model also made predictions about the components of the central executive as described by Miyake and colleagues (2000). Specifically, ACT posited that anxiety interferes with the inhibition and shifting functions.

The application of ACT to social anxiety has been tested in several recent studies (Amir & Bomyea, 2011; Judah, Grant, Lechner, & Mills, 2013; Judah, Grant, Mills, & Lechner, 2013; Wieser, Pauli, & Mühlberger, 2009). For example, Amir and Bomyea (2011) found that subjects with SAD showed reduced working memory capacity compared to healthy controls for neutral, but not threatening, stimuli. Drawing from ACT, they interpreted their findings as indicating benefits in stimulus-driven attention for threat due to anxiety, coupled with general deficits in attentional control. Wieser and colleagues (2009) examined subjects high and low in social anxiety as they completed an emotional mixed antisaccade task. Subjects were cued to look toward (prosaccade) or away from (antisaccade) emotional or neutral faces which appeared to the side of a centrally located fixation cross. Results suggested that socially anxious individuals displayed more erratic saccades toward all faces compared to the control group in the anti-saccade condition. The authors interpreted this as evidence of impaired inhibitory control over stimulus-driven prosaccades. Similarly, the findings of Judah and colleagues (discussed above) suggested that socially anxious individuals utilized greater neural resources for response preparation. Thus, research investigating the application of ACT to social anxiety has generally been supportive.

Cowan's Embedded Processes Model.

Cowan's (1995, 1999) model of working memory is among the most notable competitors with Baddeley's model. Cowan described working memory as the accessibility of cognitive processes to awareness. Cowan's model avoids distinct structures or functions involved in working memory by positing that processes associated with working memory operate through various embedded components. The broadest component described by Cowan is short-term memory, which is conceptualized as activated long term memory. The second is the "focus of attention," a limited capacity component with a ceiling of approximately four items. Cowan suggested that the components and their interaction encompass the various functions associated with working memory.

Theories of attention and working memory are important to cognitive models of SAD. Many cognitive processes in these models, including attentional biases, utilize theories of attention and working memory. Thus, drawing hypotheses from these theories may be a productive strategy for advancing cognitive models of SAD.

Event-related Potentials

One limitation that has faced the majority of studies examining attentional biases is their inability to distinguish between stages of attention. Researchers have attempted to do so by varying the stimulus onset asynchronies (SOAs) in dot-probe tasks or by examining discrete time windows using eye tracking (Schofield et al., 2012). Within the broader literature of attention, researchers have used event-related potentials (ERPs) to measure attentional processes more directly. ERPs have several advantages, the most cited of which is their high temporal resolution (Luck, 2005). ERPs are derived from the electroencephalogram (EEG), which consists of a continuous measurement of summated post-synaptic potentials that are transferred to the scalp via volume conduction. Thus, ERPs represent a more direct measure of the neural basis of cognitive processes than reaction time or eye tracking. Research also suggests that ERPs may have better reliability than certain reaction time tasks and that they may detect biases not evident in behavioral data (see Kappenman, Farrens, Luck, & Proudfit, 2014).

EEG is measured with a network of electrodes (typically 9-256) applied to the scalp using a standard method to ensure consistent positioning, the most common of which is the 10-20 system. These electrodes are usually silver chloride, and the EEG is conducted to the electrodes via electroconductive gel or sponges soaked in a saline solution. Voltage changes are measured between each of the active EEG electrodes and a reference in a more electrically neutral location, such as the earlobe or mastoid process. The re-referencing of the EEG to the average of all EEG sites or to the average of both mastoids is commonly done to reduce the influence of the reference location on the signal (see Keil et al., 2014). The electrical signal is commonly amplified online by several orders of magnitude. In order to prevent aliasing, a problem which occurs when the sampling rate is insufficient to distinguish between two or more frequencies, the sampling rate must be at least double the highest frequency in the EEG, a principle known as the Nyquist-Shannon Theorem. Thus, a sampling rate between 200 and 1000 Hz is typically used. To further prevent aliasing, an online high pass filter set between .01 and .1 Hz is used. A low pass filter is typically set between 35 and 100 Hz to attenuate high frequency signals. Ideally, low pass filtering is conducted offline in order to prevent distortions which occur when the entire sample is not available. Filters are best applied to the continuous EEG rather than the epoched data for the same reason (see Keil et al., 2014).

ERPs have been a particularly useful tool for examining attention (see Luck & Girelli, 1998 for a brief review). For example, Sawaki and Luck (2013) asked subjects to complete a visual search task which included task-irrelevant cue arrays which were to be ignored. The emergence of the distractor positivity (P_D), an ERP indicating effortful suppression of attention, was present during cue arrays, suggesting that the reorientation of attention from a distractor is active rather than passive. The use of ERPs to address the debate regarding the locus of attention represents another example of the usefulness of ERPs. Theorists have long debated whether individuals can filter incoming information before perceptual processes (i.e., early selection) or can only do so after they have been perceived (i.e., late selection; see Luck & Girelli, 1998). In support of early selection, various studies using paradigms which include attended and unattended areas of the visual field have found voltage differences between attended and unattended locations that emerge between 60 and 100 ms (i.e., the P1 and N1; Mangun & Hillyard, 1988; Van Voorhis & Hillyard, 1977; Eason, Harter, & White, 1969).

As detailed previously, ERPs have been used to test cognitive models of SAD. One limitation of many ERP studies is that that results may be difficult to interpret because many components are modulated by various factors, some of which are unknown, some which may be aspects of the task itself. For example, the P3 is sensitive to local probability, arousal, and effort (see Kok, 2001). Therefore, it is difficult to draw clear inferences about attention from studies in which anxious arousal, enhanced effort due to anxiety, and other factors can modulate the ERPs. To overcome this limitation, research is needed using ERPs which are minimally contaminated by other processes. The contralateral control method is an approach for isolating ERPs which takes advantage of the hemispheric organization of the visual system in order to isolate ERPs associated with visual attention from other neural processes (Gratton, 1998). The contralateral layout of the visual system results in several ERPs which can be isolated as differences between contralateral and ipsilateral activity, including the N2pc and contralateral delay activity. By comparing activity in one hemisphere to another within subjects, noise levels are greatly reduced (see Luck, 2005).

N2pc.

The N2pc, first observed by Steven Hillyard's research group (Heinze, Luck, Mangun, & Hillyard, 1990; Luck and Hillyard, 1994), has been particularly useful for examining selective attention. The N2pc was named for both its negative going voltage (N), onset at approximately 200 ms post stimulus (2), and posterior contralateral scalp distribution (pc). More precisely, the N2pc is maximal at posterior-occipital sites contralateral to the side of the visual field that is attended. The N2pc is calculated as a difference wave between laterally corresponding posterior-occipital sites (i.e., $V_C - V_I$, where V_C is voltage at contralateral sites and V_I is voltage at ipsilateral sites; Luck, 2012). Research using magnetoencephalography with EEG has suggested that the N2pc represents the activity of neurons in visual cortex, particularly extrastriate and inferotemporal areas (Hopf et al., 2000). The visual search paradigm is commonly used to elicit the N2pc. In this task, subjects fixate on a centrally located fixation point throughout the study as they view a series of stimuli presented to each side of the visual field. Traditionally, these stimuli consist of colored or shaded shapes, such as rectangles which may be oriented vertically or horizontally. Subjects are given a target stimulus and required to identify the side of the screen on which it appears. Alternatively, subjects are cued to attend to one hemifield and report whether the target object is present. Studies suggest that the N2pc can be modulated by task irrelevant factors, provided that attention is consistently deployed in preferential selection of the hemifield which it occupies (e.g., Eimer & Kiss, 2007).

Notably, researchers have used the N2pc to examine attentional biases. For example, a visual search task was used to assess whether spider phobics display attentional biases toward images of spiders (Weymar et al., 2013). Stimulus arrays included spiders and butterflies as targets amongst images of flowers. The results suggested that spider phobics, but not healthy controls, showed greater N2pc amplitude for spider versus butterfly targets. In another example more germane to the current study, Eimer and Kiss (2007) modified a visual search task so that the stimuli consisted of a field of neutral faces with a single fearful face or a field of fearful faces with a single neutral face. Participants were instructed to detect changes in the luminance of the fixation cross so that the task did not require the allocation of attention to the facial stimuli. Nevertheless, the N2pc was present and suggested biased attention toward the side of the visual field which contained a fearful face amidst a field of neutral faces. Importantly, a comparison of the N2pc and reaction time in a dot-probe task found that reaction time did not evidence biases which were indicated by the N2pc (Kappenman et al., 2014). Thus, the N2pc may be sensitive to attentional biases not detected in studies relying solely on behavioral data.

Contralateral Delay Activity.

Researchers have observed a negative waveform that occurs when subjects maintain a visual stimulus array in working memory and persists until the information is no longer needed (e.g., Klaver, Smid, & Heinze, 1999; see Perez & Vogel, 2012). This activity was more systematically explored and labeled the contralateral delay activity (CDA) by Vogel and Machizawa (2004). The CDA is typically elicited using a change detection task, in which participants view stimulus arrays presented to each side of the visual field with a cue to attend toward one side or the other. This cue may be presented before the array, after it, or after a short delay. After a retention period which typically lasts 500-900 ms, a test array appears, and subjects must report whether there are any changes in task relevant features to the cued side of the visual field. The CDA emerges approximately 275 ms after subjects are cued to preferentially maintain information from one side of the visual field over the other (Perez & Vogel, 2012). As with the

N2pc, foveation on a centrally located fixation cross throughout each trial is critical for eliciting the CDA. The CDA is isolated at posterior occipital sites and computed as a difference between contralateral and ipsilateral voltage. These similarities to the N2pc reflect their common basis in the visual system. Source localization research on the CDA has yet to draw precise conclusions about its neural generators. However, limited neuroimaging research using visual working memory tasks suggests that the intraparietal sulcus is a likely source of the CDA (Todd & Marois, 2004; Xu & Chun, 2006), a notion that is consistent with its scalp topography (Perez & Vogel, 2012). Research suggests that there is a strong correlation (e.g., r = .78; Vogel & Machizawa, 2004) between working memory capacity as assessed by behavioral performance on a change detection task and the change in CDA amplitude from small (i.e., 2) to large (i.e., 4) set sizes. Further supporting the hypothesis that the CDA reflects working memory storage, Woodman and Vogel (2008) manipulated the instructions about the stimulus information (e.g., color, orientation) that should be attended in a change detection task. Although the presented stimuli were identical for each condition, the researchers found that subjects who were asked to remember both color and orientation showed an additive effect on CDA amplitude at each set size. This is consistent with the notion that the CDA reflects quantity of information in working memory storage.

The temporal course of the CDA strongly supports its relationship to visual working memory. Its onset is immediately following the N2pc in conditions where information must be maintained over time, and its offset occurs when this information is no longer needed. Although the CDA does not have a clear peak, it typically reaches its maximum amplitude about 450 ms after the stimulus array is presented (Perez & Vogel, 2012). This latency is affected by storage demands such that it is delayed approximately 42 ms per stored item, a finding that is consistent with research suggesting that working memory consolidation is delayed 30-50 ms per object (Gegenfurtner & Sperling, 1993; Vogel, Woodman, & Luck, 2006; see also Perez & Vogel, 2012).

Vogel and colleagues have engaged in a series of elegant experiments designed to systematically evaluate alternative explanations for the CDA. The breadth of attention confounded early results because larger set sizes resulted in stimulus arrays which occupied a broader visual angle. Therefore it was unclear to what extent the CDA was driven by working memory load versus spatial scope. McCollough, Machizawa, and Vogel (2007) manipulated the space between stimuli in order to control the breadth of the stimulus field and observed that this did not modulate the CDA. A second alternative explanation was that the CDA reflects arousal or effort, a potential confound of increasing the stimulus set size. To test this, Vogel and colleagues used larger set sizes consisting of 6, 8, and 10 stimuli. They predicted that the CDA should asymptotically reach capacity limits at approximately four items if due to working memory or continue to demonstrate differences at increasing set sizes if due to arousal/effort (McCollough et al., 2007; Vogel & Machizawa, 2004). Their findings, that CDA amplitude did not differ between set sizes greater than four, suggests that the CDA is not modulated by task difficulty or arousal.

One use of the CDA that may be particularly important for the SAD attentional bias literature is the examination of the maintenance of task-irrelevant information. Vogel, McCollough, and Machizawa (2005) examined this using a change detection task with dichotomously colored stimuli and instructions to attend only to stimuli which were one of the colors. Trials included either to-be-attended stimuli only or a mix of these stimuli with other-colored distractors. They found that working memory capacity predicted inefficient storage, as indicated by larger CDA for trials containing distractors, which suggests the storage of task-irrelevant information. In another study, Williams and Woodman (2012, experiment 3) modified a change detection task so that the cue to attend only one side of the visual field was presented after a short delay following each stimulus array. This allowed them to assess the CDA without task demands to preferentially store information on either side of the visual field (i.e., uncued CDA) as well as to measure the CDA after being cued to do so (i.e., cued CDA). They found that the CDA was only present following the cues, suggesting that subjects did not prioritize either side of the visual field in working memory unless directed to do so. This approach is useful to the current study in that it enables the evaluation of biases in working memory in both undirected and directed conditions.

Other researchers have extended this use of the CDA to examine questions pertinent to psychopathology. For example, Owens, Derakshan, and Koster (2012) found that subjects high in dysphoric symptoms displayed lower working memory capacity and reduced filtering of irrelevant information compared to non-dysphoric controls. Another study examined filtering efficiency of threat-related distractors in groups of subjects high or low in trait anxiety (Stout et al., 2013). Both groups displayed storage of threatening distractors, but this effect was larger for anxious subjects. Thus, the utility of the CDA for examining automatic storage of task-irrelevant information may be useful for determining whether socially anxious individuals preferentially store socially threatening information in working memory.

Current Study

Evidence supports the predictions of cognitive models that socially anxious individuals preferentially select threatening information in the environment. However, the literature is inconclusive with respect to subsequent attentional deployment. Furthermore, the majority of previous studies have relied upon methodologies which do not measure attention directly. These studies are further limited by a reliance on approaches with poor temporal resolution, such as the dot-probe task. Thirdly, studies have not examined the prediction that self-focused attention moderates these biases, despite this hypothesis being explicit in cognitive models. The objective of the current study is to use lateralized ERPs to address these gaps and advance the state of the evidence with respect to cognitive theories of SAD.

The aim of the current study is to examine attentional biases in the selection and maintenance of socially threatening facial expressions. A secondary goal is to examine how these biases are affected by self-focused attention. The study will use a novel modification of the change detection task, which allows for the examination of working memory maintenance with and without task demands. Attentional biases will be assessed at two stages using ERPs which are well-validated for this purpose. The N2pc will be used to examine early biases in selection, and the CDA will be used to evaluate later biases in working memory maintenance.

It is predicted that socially anxious subjects will display selection bias for evaluative faces as indicated by larger N2pc amplitude for disgust compared to neutral faces. This bias is expected to persist after the offset of the face stimuli as socially anxious subjects show biases in working memory maintenance of threatening material as indicated by CDA amplitude. Following instructions to attend to one side of the visual field, it is expected that socially anxious subjects will show smaller CDA for attend neutral trials relative to controls, indicating that neural resources are being allocated for storage of task-irrelevant threatening material on the opposite side of the visual field. It is predicted that they also will display larger CDA amplitude for attend threat trials compared to controls. Both of these predictions are in line with the hypothesis that socially anxious subjects display late attentional biases toward threat (i.e., difficulty disengaging attention). The self-focus (i.e., false heart rate feedback) manipulation is expected to interact with social anxiety group such that the hypothesized effects are enhanced for socially anxious, but not non-anxious, subjects. This is consistent with data which suggest that working memory load leads to difficulty disengaging attention from threat (see Judah, Grant, Lechner, & Mills, 2013). Alternatively, self-focus may reduce attentional biases in selection and maintenance for external cues, including those which are threatening, resulting in a reduced N2pc and CDA for threat (see Clark & Wells, 1995; Clark & McManus, 2002).

CHAPTER III

METHODOLOGY

Participants

The sample was recruited from the undergraduate student body of a large Midwestern university using an online research participation system through which students obtain course credit. The sample consisted of 26 females (62%) and 16 males (see Table 1). Thirty-five participants identified as Caucasian (83.3%), three as African-American (7.1%), one as Native American (2.4%), one as bi-racial (2.4%) and two preferred not to respond (4.8%). Scores on the Social Interaction Anxiety Scale (SIAS) were used in an extreme groups approach. Participants completed the SIAS as part of a screener for the online research participation system. Those with scores falling within group cutoff scores were allowed to sign-up for the study voluntarily and were recruited using e-mail. The SIAS was administered a second time, along with other self-report measures, prior to the experiment, and these scores were used to divide the sample into social anxiety groups. In line with similar studies (e.g., Judah, Grant, Lechner, & Mills, 2013; Judah, Grant, Mills, & Lechner, 2013), subjects scoring one standard deviation or greater above the mean reported for the original normalization of the measure (Mattick & Clarke, 1998) were considered high in social anxiety (HSA). Those scoring below the mean constituted the low social anxiety (LSA) group. A power analysis using effect sizes from similar studies (Stout et al., 2013; Owens et al., 2012) and Cohen's (1988) procedures suggested that 15 - 18 subjects were needed for each group.

Materials

Demographics Form. A brief questionnaire was used to obtain information about each participant's sex, race, education, and other pertinent demographic data.

Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998). This is a self-report measure of fears related to social interactions. It consists of 20 Likert scale items ranging from "0" to "4" with higher scores reflecting higher levels of social anxiety. The SIAS is currently among the most commonly used self-report measures of social anxiety, and psychometric studies support its validity and reliability (Osman, Gutierrez, Barrios, Kopper, & Chiros, 1998). Internal consistency was excellent for this study (Cronbach's α = .94).

Anticipatory Social Behaviours Questionnaire (ASBQ; Hinrichsen & Clark, 2003). The ASBQ is a self-report measure of anticipatory processing about upcoming social situations. It consists of 12 items with response options ranging from "1" to "4" with higher scores indicating higher levels of anticipatory processing. Mills and colleagues (2013) identified two correlated subscales which they labeled "Preparation" and "Avoidance," the latter of which was more closely associated with maladaptive behaviors. Internal consistency was good for the overall scale (α = .88) and for the Avoidance (α = .81) subscale, and acceptable for the Preparation subscale (α = .79).

Focus of Attention Questionnaire (FAQ; Woody, 1996). The FAQ consists of 10 items ranging from "0" to "10" which evaluate the extent to which one attends to thoughts, physiological changes, and behaviors while delivering a speech. Following the approach used by Mills and colleagues (2013), each item was altered to assess attention during a general social interaction. Internal consistency was high (α = .82).

Attentional Control Scale (ACS; Derryberry & Reed, 2002). The ACS consists of 20 self-report items which assess executive control of attention. Judah, Grant, Mills, and Lechner (2014) identified two correlated subscales, "Focusing" and "Shifting" which demonstrated discriminant and predictive validity. The latter subscale correlated with working memory capacity as assessed by a letter-number sequencing task. Internal consistency was good for the overall scale (α = .84) and inhibition subscale (α = .83), and acceptable for the shifting subscale (α = .68).

Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996). The BDI-II assesses symptoms of depression using 21 self-report items ranging from “0” to “3” with higher scores reflecting greater severity. Research supports the reliability and validity of the BDI-II (Storch, Roberti, & Roth, 2004). Internal consistency was high for the present study (α = .85).

Anxiety Sensitivity Index-3 (Taylor et al., 2007). The ASI-III is a revised version of the original ASI (Peterson & Reiss, 1992), which was designed to assess fear of somatic sensations related to arousal and anxiety. The ASI-3 includes 18 items arranged in three empirically derived subscales which measure Physical, Cognitive, and Social Concerns. Research supports the convergent, discriminant, and criterion-related validity of the ASI-III (Taylor et al., 2007). Internal consistency was good for the overall measure (α = .89), as well as for the Physical (α = .83) and Cognitive Concerns (α = .85) subscales. Internal consistency was acceptable for the Social Concerns subscale (α = .79).

The Wechsler Adult Intelligence Scale III, Letter-number Sequencing Subtest (Wechsler, 1997). This task involves hearing lists of letters and numbers and reciting the numbers first in numerical order followed by the letters in alphabetical order. Participants complete a maximum of 21 lists with set sizes that range from two to eight. The test is immediately discontinued if mistakes are made on all three lists for a set size. Research supports the validity of this task as a measure of working memory capacity (see Crowe, 2000).

The Radboud Faces Database (Langner et al., 2010). This is a freely available online collection of facial stimuli which have been developed and standardized for use in cognitive tasks. The database was developed to avoid differences between images in terms of luminance, distance of faces from the camera, idiosyncratic emotional expressions, and other common sources of unintended variance in facial stimulus sets. The database includes eight emotional expressions imaged from five viewing angles with eye gaze toward subject or averted to either side. All frontal view images have been validated with standardized ratings for emotional expression, attractiveness, intensity, clarity, and genuineness. This study utilized disgust and neutral faces from a frontal view with direct eye gaze. Disgust faces were used as social evaluative threat stimuli because studies suggest that socially anxious individuals perceive them as more threatening than other emotional faces, such as those depicting anger (Amir et al. 2005; Amir, Najmi, Bomyea, & Burns, 2010). In order to remove irrelevant features (i.e., neck, shoulders, and space around the head) and maximize the size of facial stimuli, each stimulus was cropped to a rectangle with a .73:1 width to height ratio.

Procedure

All procedures were approved by the Institutional Review Board. Following informed consent, participants completed all self-report measures online followed by a letter-number sequencing task and the experiment, a modified change detection task (see Fig. 1). Stimulus array positioning, presentation times, and other features of the change detection task were modeled after similar studies (Owens et al., 2012; Stout et al., 2013). Studies examining the CDA typically employ approximately 200 trials per condition (Owens et al., 2012; Qi, Ding, & Li, 2013; Sessa, Luria, Gotler, Jolicoeur, & Dell'Acqua, 2010; Vogel & Machizawa, 2004; Vogel et al., 2005; 2006; Woodman & Vogel, 2008). Artifact detection was expected to result in the rejection of as many as 25% of trials (Owens et al., 2012; Vogel & Machizawa, 2004). Thus, it was determined that the current study should consist of at least 1000 trials. To allow for an equal number of stimulus presentations in each condition, 1024 trials were needed. In order to avoid participant fatigue and minimize movement potentials, eight blocks consisting of 128 trials were administered with 20 second breaks following trials 42 and 84 within each block. Additionally, breaks of at least 60 seconds were taken between blocks (see McCollough et al., 2007; Woodman & Vogel, 2008). Participants were allowed to press a button at any time after the 60 second breaks to begin the next block.

Stimuli were presented on a Dell 19 inch LCD monitor with a refresh rate of 60 Hz. Each subject was seated so that the nasion was 70 cm from the monitor. The height of the monitor was adjusted so that its center aligned with each subject's line of sight. Stimulus presentation and event logging were controlled using PsychoPy (version 1.80; Peirce, 2007) and synched with the refresh rate of the monitor to ensure precise timing. Participants were given the following instructions prior to the task: "For this task you will see pictures of faces appearing on each side of the screen. After the faces disappear, you will be asked to remember the faces on one side of the screen. The faces will appear again, and you will indicate whether the identity of any of the faces on that side of the screen changed. Please press the (left/right trigger) if there is a change and the (left/right trigger) if there is not." Participants then completed 14 monitored practice trials with automated feedback (i.e., "Correct" or "Incorrect"). For each trial, a fixation symbol (+) appeared in the center of the monitor throughout the experiment, and participants were told to look at it throughout the study and to minimize eye movements. Participants were given random false heart rate feedback on 50% of trials. Specifically, they were told that an "×" would appear instead of the standard fixation symbol (i.e., +) if their heart rate increased. The psychological meaning of these symbols was counter-balanced across subjects to avoid the difference in the physical characteristics of the stimuli from becoming a confound (Luck, 2005). Each trial began with a centrally located fixation symbol or false heart rate symbol presented for 700 ms. This fixation symbol remained present throughout the remainder of the trial and retained its orientation. After this, a stimulus array consisting of two face pictures was presented on each side of the screen for 200 ms. The pictures on one side of the screen displayed disgust faces, and the other side displayed neutral faces. All faces were taken from the Radboud database (Langner et al., 2010). Each face picture had a 4.6^{o} horizontal offset from the fixation symbol and resided within a visual field of $13.9^{o} \times 6.5^{o}$. The visual angle subtended by the fixation symbol was 1.2^{o}, while that of each face picture was $4.7^{o} \times 6.5^{o}$. These measurements are comparable to previous research examining the N2pc and CDA (Stout et al., 2013; Owens et al., 2012; Vogel &

Machizawa, 2004). The N2pc was measured from an epoch event-locked to presentation of the face stimulus array. Following stimulus presentation, the fixation symbol remained without other stimuli for 600 ms, during which time the uncued CDA was measured. After this, an arrow pointing to the right or left (equal probability) appeared in the center of the screen for 100 ms, followed by presentation of the fixation symbol by itself for 600 ms, during which time the cued CDA was measured. After this, the test array appeared for 800 ms or until a response was made, whichever occurred first. Test arrays were identical to stimulus arrays for 50% of trials or had one face changed on the side indicated by the arrow for the other 50% of trials. Intertrial intervals varied randomly using latencies ranging from 600 - 900 ms.

Electrophysiological Recording

Electroencephalographic (EEG), electrocardiographic (ECG), and electrooculographic (EOG) data were collected using an Active II system (BioSemi, Amsterdam, The Netherlands). EEG data were collected from thirty-two channels (Fp1, Fp2, AF3, AF4, F7, F3, FZ, F4, F8, FC5, FC1, FC2, FC6, T7, C3, CZ, C4, T8, CP5, CP1, CP2, CP6, P7, P3, PZ, P4, P8, PO3, PO4, O1, OZ, and O2) positioned using the 10/20 system. Online referencing was done using two electrodes, the Common Mode Sense active (CMS) and Driven Right Leg passive (DRL) electrodes. These electrodes are part of BioSemi's basic design and substantially reduce both the common mode potential and the impedance of the ground. Electrodes were placed on each mastoid for offline re-referencing. To measure ECG, an active electrode was attached to the left side of the chest approximately six inches below the arm pit, and a passive electrode was attached to the ventral side of the trapezius. To record vertical eye movements and blinks an electrode was placed one centimeter below the left eye. Electrodes were placed one centimeter beyond the outer canthus of each eye to measure horizontal eye movements.

Electrophysiological Data Preparation

Data were sampled at 256 Hz and filtered online with a .01 – 100 Hz band pass filter. EEG data were filtered offline with a band pass filter of .1 – 30 Hz (12 dB/oct. roll-off) and referenced to the average of the mastoids. EEGLAB, version 11 (Delorme & Makeig, 2004) and ERPLAB, version 4.0 (Lopez-Calderon & Luck, 2013) were used to process the data. Independent components analysis (ICA), a commonly used computational procedure for isolating orthogonal, additive components of a signal, was used to correct for ocular artifact in the continuous data, which were then epoched by trial, beginning at 400 ms prior to the onset of the fixation cross and ending 800 ms after the presentation of the test array (3000 ms after fixation cross onset). The mean amplitude during the 200 ms prior to the most recent stimulus onset was subtracted to baseline the data. Automated routines in ERPLAB were used to remove trials containing artifact. Trials containing blinks within 200 ms of the onset of the fixation cross, stimulus array, directional cue, or test array were excluded, as were trials containing saccades during the period between the onset of the stimulus and test arrays. Additionally, a routine was used to detect and exclude trials with voltage changes exceeding 200 μV at any electrode within a 200 ms window which stepped across each trial in 50 ms increments. This process was repeated using a cutoff of 100 μV for electrodes at which measurements were taken (i.e., PO3/4, P3/4, O1/2), which were selected based on previous research which analyzes the N2pc and CDA. These ERP components were evaluated by comparing voltage between contralateral and ipsilateral electrodes as measured from the pooled occipito-parietal electrodes (P3/4, PO3/4, and O1/2). Electrodes were averaged with their laterally corresponding locations depending on which hemifield contained the stimulus being evaluated. For example, contralateral waveforms for disgust faces were averaged from electrodes on the right side of the scalp when disgust faces appeared in the left hemifield along with electrodes on the left side of the scalp when disgust faces appeared in the right hemifield. Mean amplitude within the 200-300 ms post-stimulus measurement window (Kiss, Van Velzen, & Eimer, 2008) was used to evaluate N2pc amplitude. Uncued and cued CDA amplitudes were assessed as the mean amplitudes from 300 ms post-stimulus until the onset of the next stimulus (i.e., 300-800 ms for uncued CDA, 300-700 ms for cued CDA; Vogel et al., 2005). Scalp maps representing mean amplitude within these windows were examined to verify that ERPs were maximal at occipito-parietal sites, as expected.

Manipulation Check

Previous research using pseudo heart rate feedback has included three post-task questions to verify that participants knew the meaning of the feedback stimulus and that it affected self-focus (Judah, Grant, Mills, & Lechner, 2013; Papageorgiou & Wells, 2002). Following these studies, participants were asked an open-ended question after the experiment about what caused the computer glitch. Subjects also were asked to report how much this affected self-consciousness and interfered with performance using a 0 (not at all) to 7 (extremely) scale. To evaluate differential attention to self-focus cues, the P1, an ERP which emerges at approximately 100 ms and is maximal at occipito-parietal sites, was examined. Research suggests that P1 amplitude is enhanced when subjects are vigilant for an upcoming stimulus which appears in the attended location (Hillyard, Vogel, & Luck, 1998).

Hypotheses

Hypothesis 1

It was hypothesized that N2pc amplitude would be larger at scalp sites contralateral to disgust faces for socially anxious subjects compared to non-anxious individuals, who were expected to show little to no N2pc amplitude. This would suggest greater selective attention for disgust compared to neutral facial expressions in socially anxious subjects.

Hypothesis 2

Uncued CDA amplitude was expected to be larger for disgust faces for the socially anxious group compared to the low anxious group, who were expected to show little if any CDA. This would suggest preferential maintenance of disgust compared to neutral facial expressions in the absence of task-related maintenance demands.

Hypothesis 3

Cued CDA amplitude was expected to be smaller for the socially anxious compared to the control group for “attend neutral” trials and larger for “attend disgust” trials. The first finding would suggest that socially anxious individuals have difficulty ignoring disgust facial expressions. The latter finding would suggest enhanced working memory maintenance for disgust faces when it is consistent with task demands.

Hypothesis 4

Self-focus trials, which include false heart rate feedback, were expected to interact with group such that the hypothesized effects would be exacerbated for the socially anxious group and not for controls. Cognitive theories are partially discrepant in predictions about how self-focused attention affects external attention. It is possible that self-focus reduces external attention, including attention toward threat cues. Another possibility is that self-focus results in working memory load and thereby leads to difficulty filtering threatening information from working memory (see Judah, Grant, Lechner, & Mills, 2013).

CHAPTER IV

FINDINGS

Preliminary Group Comparisons

There were no significant differences between the LSA and HSA groups in terms of demographic variables, task response rate, task performance, or working memory capacity as measured by letter-number sequencing. The number of trials retained and rejected did not differ between groups for any trial type (all *t*s < 1.30, *p*s > .22. In contrast to previous research (e.g., Judah, Grant, Mills, & Lechner, 2013), the groups did not differ in self-ratings of how much the self-focus manipulation made them more self-conscious and interfered with their performance. The HSA group scored significantly higher than the LSA group on the ASBQ and its subscales, the FAQ, the BDI-II, and the ASI-3 and its subscales, but lower on the ACS and its subscales (see Table 1).

Analytic Strategy

Prior to the main analyses, the success of the self-focus manipulation was evaluated by examining P1 amplitude differences for the standard and self-focus fixation symbols between groups. The current study used a mixed factorial design consisting of a between groups factor, Group (HSA, LSA)], and two within-subjects factors, Condition (Self-focus, No self-focus)] and Laterality (Contra, Ipsi), as well as three dependent variables (amplitudes of the N2pc, uncued CDA, cued CDA). For the cued CDA, there was an additional within-subjects factor, Target

(Disgust, Neutral). Thus, three repeated measures ANOVAs were used to evaluate the data. Significant interactions were probed using simple effects analysis with Bonferroni adjustments.

Before conducting the analyses, the data were evaluated to ensure data quality and that the assumptions of ANOVA were met. Missing self-report data were replaced with the series mean for each subject, provided that less than 5% was missing per questionnaire (Tabachnick & Fidell, 2007). No subject had more than 5% missing data for any measure. Because ANOVA is sensitive to outliers, it was planned that dependent measures with *Z* scores above 3.29 would be excluded. However, there were no cases of outliers. Assumptions for ANOVA include sampling distribution normality, homogeneity of variance, and sphericity. The normality assumption was tested by examining the skewness and kurtosis of the residuals, with the assumption supported by values below 2.0 and 4.0, respectively (Tabachnick & Fidell, 2007). Skewness and kurtosis values were within acceptable limits for the N2pc and uncued CDA. For the cued CDA, the residuals for disgust targets on self-focus trials were slightly negatively skewed for both ipsilateral (-2.02) and contralateral sites (-2.14). Additionally, there was evidence of kurtosis of the residuals for sites contralateral to disgust targets on standard trials (4.33), both contralateral (5.91) and ipsilateral sites (6.35) for disgust targets on self-focus trials, and for ipsilateral sites for neutral targets on self-focus trials (4.07). Thus, the normality assumption for the cued CDA was considered questionable. The normality assumption also rests on balanced sample sizes between groups and the use of two-tailed tests, both of which were the case in the present study. *F*max was used to assess homogeneity of variance, with values below 10 supporting the assumption. All values were below 10 (N2pc = 1.84, uncued CDA = 3.33, cued CDA = 6.07). Assuming sphericity was unnecessary because all factors consisted of only two levels.

Effect sizes for significant effects were calculated using η^2 and Cohen's *d*. Conventions for interpreting η^2 are that effect sizes above .26 are large, those less than this and above .13 are medium, and those below this and above .02 are small. Cohen's *d* is conventionally interpreted as large if .80 or greater, medium if .50 or greater, and small if .20 or greater.

Manipulation Check

All subjects who were included in the analyses recalled that the change in the fixation symbol was a software glitch which indicated that their heart rate had accelerated. Subjects reported moderate increases in self-consciousness (*M* = 2.98, *SD* = 1.80) and interference (*M* = 2.69, *SD* = 1.98) when heart rate cues were presented. Pooled occipito-parietal sites (OZ, O1/2, PO3/4) were examined within the 75-125 ms window to evaluate the P1 following the onset of fixation symbols. A 2 [Group (HSA, LSA)] x 2 [Condition (Standard, Self-Focus)] mixed ANOVA revealed a main effect for Condition, $F(1,40) = 5.13$ p = 03, $\eta_p^2 = .10$, such that P1 amplitude was larger for heart rate cues (*M* = .47, *SD* = 1.21) compared to standard fixation symbols (*M* = .16, *SD* = 1.36; *d* = .24). There also was a main effect for Group, $F(1,40) = 6.45$, $p = .014$, $\eta_p^2 = .12$, suggesting that HSA subjects displayed a larger P1 (*M* = .79, *SD* = 1.24) compared to LSA subjects (*M* = -.16, *SD* = 1.17; *d* = .79). The interaction between Group and Condition was not significant, $F < 1.0$. These analyses supported the manipulation by suggesting that 1) subjects were more vigilant for self-focus cues than for standard fixation symbols and 2) HSAs were more vigilant than LSAs for the fixation symbols in general.

Primary Analyses

Analyses of the N2pc and uncued CDA were conducted on pooled occipito-parietal sites P3/P4, PO3/PO4, and O1/O2. A 2 [Group (HSA, LSA)] x 2 [Condition (Standard, Self-Focus)] x 2 [Laterality (Contralateral, Ipsilateral)] mixed ANOVA was used to test early biased attention for disgust faces (see Fig. 3). There was a significant three way interaction of Group, Condition, and Laterality, $F(1,40) = 7.72$, $p < .01$, $\eta_p^2 = .16$, such that HSA subjects showed greater negativity at sites contralateral (*M* = 2.03, *SD* = 3.85) than sites ipsilateral to disgust faces for standard trials (*M* = 2.20, *SD* = 3.88; $p = .01$, $\eta_p^2 = .16$), but not when self-focus cues were present, p = .24. In contrast, LSA subjects showed marginally significant negativity at contralateral (M = 1.75, SD = 3.95) relative to ipsilateral sites (M = 1.88, SD = 3.94, p = .06, η_p^2 = .08) for disgust faces for self-focus trials, but not standard trials, p = .76. Thus, HSA subjects showed an N2pc supporting early biased selective attention for disgust faces, but not when self-focus cues were present, whereas LSA subjects showed a marginally significant bias only when the self-focus cues were present. There were no other significant main effects or interactions.

For the uncued CDA, there was a significant three way interaction of Group, Condition, and Laterality, $F(1,40) = 5.43$, p = .025, η_p^2 = .12 (see Fig. 4). Follow-up pairwise comparisons indicated that on standard trials, HSAs showed greater contralateral (M = .66, SD = 2.38) than ipsilateral negativity (M = .84, SD = 2.40) for disgust faces, $p < .01$, η_p^2 = .16, but this effect was not present for trials with self-focus cues, p = .16, nor was it significant for LSA subjects for trials with self-focus cues, p = .53, or without them, p = .96. No other comparisons, main effects, or interactions were significant.

A 2 [Group (HSA, LSA)] x 2 [Condition (No Self-Focus, Self-Focus)] x 2 [Target (Disgust, Neutral) x 2 [Laterality (Contralateral, Ipsilateral)] mixed ANOVA was used to test how biased attention competes with task instructions as measured by the cued CDA (see Figs. 4 & 5). There was a marginally significant main effect for Laterality, $F(1,40) = 3.93$, p = .054, η_p^2 = .09. This was qualified by an interaction between Group and Laterality, $F(1,40) = 5.11$, p = .029, η_p^2 = .11. Unexpectedly, LSA subjects showed greater negativity at sites ipsilateral to targets (M = .80, SD = 2.15) than at contralateral sites (M = 1.09, SD = 2.27; p = .004, η_p^2 = .19). No significant pairwise comparisons were found for the HSA group, nor were there other significant main effects or interactions.

Supplementary Analyses

Examination of the arrow-locked ERP waveform containing the cued CDA suggested the presence of the N2pc. Analysis of the second N2pc was done on pooled voltage at P3/P4, PO3/PO4, and O1/O2. A 2 [Group (HSA, LSA)] x 2 [Condition (No Self-Focus, Self-Focus)] x 2 [Target (Disgust, Neutral) x 2 [Laterality (Contralateral, Ipsilateral)] mixed ANOVA was used to examine the N2pc. There was a main effect for Laterality, $F(1,40) = 5.98$, $p = .02$, $\eta_p^2 = .13$, such that subjects showed greater negativity at sites contralateral ($M = 2.57$, $SD = 2.29$) than sites ipsilateral to targets ($M = 2.70$, $SD = 2.34$). Thus, subjects showed biased selective attention for the hemifield indicated by the arrow.

The test array at the end of each trial provided an additional opportunity to examine the N2pc and sustained posterior contralateral negativity (SPCN). The N2pc was evaluated using a 2 [Group (HSA, LSA)] x 2 [Condition (No Self-Focus, Self-Focus)] x 2 [Target (Disgust, Neutral) mixed ANOVA with the difference wave (contra minus ipsi) as the dependent variable. For the N2pc, there was a marginally significant main effect for Group, $F(1,40) = 3.98$, $p = .053$, $\eta_p^2 = .09$, such that LSA subjects trended toward a larger N2pc for targets ($M = -.24$, $SD = .91$) relative to HSA subjects ($M = .16$, $SD = .96$). There was also a marginally significant interaction between Group and Laterality, $F(1,40) = 3.98$, $p = .053$, $\eta_p^2 = .09$. These effects were qualified by a significant three way interaction between all factors, $F(1,40) = 4.64$, $p = .037$, $\eta_p^2 = .10$. Follow-up pairwise comparisons of the difference waves suggested that for self-focus trials, HSA subjects showed a significantly more positive N2pc for neutral targets ($M = .40$, $SD = .79$) compared to disgust targets ($M = .027$, $SD = .76$; $p = .008$, $d = .48$, $\eta_p^2 = .16$). This positive N2pc indicates greater voltage at sites contralateral to distractors relative to ipsilateral sites, indicating greater attentional bias for disgust compared to neutral distractors.

A 2 [Group (HSA, LSA)] x 2 [Condition (No Self-Focus, Self-Focus)] x 2 [Target (Disgust, Neutral) x 2 [Laterality (Contralateral, Ipsilateral)] mixed ANOVA was used to evaluate the CDA for faces in the test array. There was a main effect for Laterality, $F(1,40) = 12.40$, $p < .001$, $\eta_p^{2\,=}$ .24, suggesting that subjects showed greater negative voltage at electrodes contralateral to targets (M = 3.36, SD = .58) relative to ipsilateral electrodes (M = 3.68, SD = .58; d = -.55). There were no other significant main effects or interactions.

CHAPTER V

CONCLUSION

As hypothesized, socially anxious subjects, but not controls, showed a bias for disgust facial expressions as indicated by enhanced N2pc amplitude. Further, this bias persisted in working memory after these faces disappeared, as indicated by greater CDA amplitude. Contrary to the hypothesis, biased preference for threat was not evident after participants were cued to attend to one hemifield. Instead, an unexpected effect was observed, namely, that individuals with low levels of social anxiety showed a reverse CDA effect for targets that was not present for socially anxious subjects. In the context of self-focus cues, socially anxious subjects did not show a bias for disgust faces as indicated by N2pc or CDA amplitude. Unexpectedly, control subjects displayed a bias for disgust faces when self-focus cues were present, but this bias did not persist in working memory, as indicated by lack of an effect on the CDA.

Discussion of Findings

The results support and advance cognitive models of social anxiety disorder. Biased attention toward social threat is a cornerstone of these theories, but only a handful of studies have tested this using ERPs as a direct measure of attention and working memory. Previous studies have evaluated enhanced P1 amplitude (e.g., Mueller et al., 2009; Kolassa et al., 2007, Peschard et al., 2013), P3 amplitude (Moser et al., 2008), and other components (e.g., van der Molen et al.,

2013) in socially anxious subjects to investigate attentional biases. A review of the literature suggested that this is the first study to investigate attentional biases in social anxiety using lateralized ERPs, specifically, the N2pc and CDA. The results suggest that this approach may aid in resolving unanswered questions about relationships between cognitive processes and social anxiety.

A key finding of this study is that socially anxious subjects show biases in selective attention (N2pc) and working memory maintenance (uncued CDA) for disgust relative to neutral faces and that individuals low in social anxiety do not. This is generally in line with other studies, which have found that socially anxious subjects exhibit early attentional biases (e.g., Peschard et al., 2013). The current study furthers this literature by examining biases in selection for disgust faces from a visual array which also contained neutral faces. Additionally, the uncued CDA findings advance the field by suggesting that socially anxious individuals preferentially maintain disgust faces in working memory even after they are no longer present. This sustained bias in working memory may be relevant to the ongoing question of the conditions that affect whether socially anxious individuals disengage from social threat stimuli at late stages of processing. The current study supports a sustained bias for social threat, although it is unclear whether changes to the experimental design might have produced different results. For example, Judah, Grant, Lechner, and Mills (2013) found that cognitive load was associated with sustained attention to threatening faces. It is possible that the current task, which required participants to store features of four faces simultaneously, resulted in high cognitive load, thereby depleting executive resources which might be used to disengage attention from threatening stimuli if this load were not present. Further research is needed to investigate this and other potential moderators of this effect.

These data also suggest interesting effects of self-focused attention on attentional biases. There is a lack of clear consensus among theories (see Schultz & Heimberg, 2008) as to whether self-focused attention increases the salience of external social threat stimuli and thereby increases vigilance (Heimberg, Brozovich, & Rapee, 2010; Rapee & Heimberg, 1998) or reduces the availability of attentional resources to process external stimuli (Clark & McManus, 2002; Clark & Wells, 1995). This study suggested that the presence of a cue allegedly indicating accelerated heart rate resulted in a lack of bias for disgust faces in selective attention (i.e., N2pc) and in working memory (i.e., uncued CDA) among socially anxious individuals. This would seem to support the prediction that self-focused attention reduces processing of external stimuli. Clark and Wells (1995) hypothesized that one mechanism which maintains social phobia is that self-focus may prevent processing of external information which would disconfirm social fears. However, it also may be posited that self-focus would interfere with processing of ambiguous or socially threatening information, which may interfere with habituation and/or new learning in social contexts. Thus, self-focus may share features with avoidance behaviors which prevent adaptive learning and maintain anxiety.

Unexpectedly, the self-focus manipulation resulted in marginally significant biased selective attention (i.e., N2pc) for disgust faces among the low anxious subjects. This suggests a differential effect of the manipulation on attentional biases among individuals high and low in social anxiety. Whereas it resulted in reduced bias for the socially anxious subjects, it increased this bias in those with low social anxiety. Importantly, this bias was not maintained after the offset of the stimulus array, and subjects low in social anxiety did not show biases in working memory for disgust faces, even for self-focus trials. The effect of self-focus on the N2pc suggests differences in how the groups processed cues that heart rate is elevated. It also may suggest a mechanism for the development of social anxiety. Specifically, attention to physiological symptoms of anxiety may be involved in the reallocation of attention to detect sources of threat. Future research is needed to determine whether this effect is replicable, particularly due to its marginal significance.

Surprisingly, a cued CDA was not evident in this study. It was expected that subjects would show greater negativity at contralateral compared to ipsilateral sites for targets in the interval preceding the test array. Counter to this hypothesis, the low social anxiety group showed the opposite pattern, namely, greater negativity at ipsilateral than contralateral sites. Although this effect was not anticipated, supplementary analyses suggested that both groups showed an N2pc for the hemifield to which the arrow cue directed them to attend. Thus, subjects showed early selective attention in favor of the hemifield containing target faces. Examination of the waveforms suggested that the ipsilateral negativity emerged around 400 ms. There are two possible interpretations of what this activity means (see Arend & Zimmer, 2011). First, it may indicate preferred working memory storage for distractors, but this seems unlikely, especially given the early N2pc preference for targets. A second possibility is that it reflects the ipsilateral hemisphere actively suppressing attention to distractors. Although lack of clarity of the psychological meaning of the effect means that strong conclusions cannot be drawn, the possibility that it represents suppression of distractors is in line with the hypotheses. This interpretation also is supported by recent research using a change detection task that noted the presence of a similar effect, termed ipsilateral delay activity, when distractors were actively inhibited (Arend & Zimmer, 2011). In the case of this study, the ipsilateral delay activity would suggest that individuals low in social anxiety were able to suppress distractors regardless of their emotional valence, but those high in social anxiety were not. Previous research has suggested that anxiety (Eysenck et al., 2007), including social anxiety (Judah, Grant, Mills, & Lechner, 2013), is associated with impairments in cognitive control. Thus, it may be that subjects high in social anxiety were less likely to utilize a memory strategy which involved filtering distractors from working memory. Although the implications of the ipsilateral delay activity for the low social anxiety group could be informative, only speculation about its meaning is possible at this time.

Larger P1 amplitude for self-focus cues relative to standard fixation symbols suggests that subjects were attuned to the psychological meaning of the cues. These symbols were counter-balanced across subjects, and each appeared for 50% of trials. Thus, their physical characteristics and frequency are ruled out as alternative explanations for the P1 effect. HSA subjects showed larger P1 amplitude for fixation symbols in general compared to LSAs, suggesting greater vigilance for the appearance of task irrelevant information about their physiological arousal. Unlike previous research which has found that false heart rate feedback increased self-consciousness and perceived interference in subjects high in social anxiety relative to low socially anxious controls (e.g., Judah, Grant, Mills, & Lechner, 2013), these ratings did not differ between groups in this study. One possibility is that the relatively frequent presentation (i.e., 50% of trials) resulted in greater habituation than in the study conducted by Judah and colleagues (2013), which presented this feedback on 20% of trials.

Limitations

There are important limitations to these data which should be considered. First, the use of a non-clinical, undergraduate sample may be seen as a threat to the generalizability of the findings to social anxiety disorder. However, recent perspectives on psychopathology (e.g., RDoC) suggest that research is needed which targets understanding symptoms, behavior, and neural function rather than diagnostic categories. Additionally, theoretical perspectives consider social anxiety as a continuum along which social anxiety disorder represents maladaptively high levels of anxiety (Crome, Baillie, Slade, & Ruscio, 2010; Rapee & Heimberg, 1997). Another limitation is that conclusions about ERPs, including those made in this study, rely on extensive background research documenting their psychological meaning. This presents a particular problem for interpreting the cued CDA effect for the low social anxiety group, which evidenced ipsilateral negativity. Future studies are needed to clarify this finding and to better understand the psychological processes involved in the CDA and other ERPs related to working memory.

In summary, this study has important theoretical and treatment implications. It resulted in clear evidence of attention biases, which supports cognitive models of social anxiety disorder. The data address a long-standing uncertainty among theories regarding the effect of self-focused attention on external attention to threatening stimuli. New research questions are suggested by the results, and these may be useful in continuing to hone cognitive theories. In addition to the theoretical implications of the study, the findings may be important for treatment considerations. Cognitive behavioral therapy (CBT) for social anxiety disorder, which relies on exposure therapy, may benefit from this and other studies which are progressively explicating how attentional biases maintain social fears. For example, these data may be taken as part of a building literature suggesting that self-focused attention may reduce processing of threat in the environment, which may impact the success of exposure. This may suggest that self-focused attention should be considered an important target for behavioral interventions for SAD. More research is needed to further our understanding of internal and external attentional biases, how they impact treatment, and how current CBT may be informed by this information.

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APPENDICES

Table 1. Group Comparisons on Demographic, Cognitive, Task, and Symptom Measures

Variables	HSA Group		LSA Group		Significance Test	
	M (Count)	*SD* (%)	*M* (Count)	*SD* (%)	*t* (χ^2)	*p*
Sex	--	--	--	--	(.77)	.38
Male	(9)	(45%)	(7)	(32%)		
Female	(11)	(55%)	(15)	(68%)		
Age	19.80	5.34	18.95	1.81	1.91	.18
Ethnicity	--	--	--	--	(4.95)	.29
Caucasian	(18)	(90.0)	(17)	(77.3)		
African American	(0)	(0)	(3)	(14.6)		
Native American	(0)	(0)	(1)	(5.5)		
Bi-racial	(1)	(5.0)	(0)	(0)		
No Response	(1)	(5.0)	(1)	(5.5)		
ASBQ	35.10	6.09	24.73	6.30	5.41	< .001
Prepare	15.55	2.87	11.64	3.35	4.05	<.001
Avoid	13.45	3.00	8.95	3.39	4.53	<.001
FAQ	27.60	6.45	21.36	5.63	3.35	.002
ACS	43.50	7.69	52.27	6.66	3.96	<.001
Focusing	13.80	3.35	18.55	3.36	4.58	<.001
Shifting	11.25	1.94	13.05	2.44	2.62	.012
BDI-II	14.75	9.18	7.36	6.08	3.10	.004
ASI-3	35.20	8.64	25.50	7.73	3.84	<.001
Physical Concerns	10.50	4.11	8.09	3.04	2.17	.04
Cognitive Concerns	10.10	3.42	7.50	3.49	2.44	.02
Social Concerns	14.60	4.26	9.91	3.04	4.14	<.001
Letter-number Seq.	41.21	30.84	35.38	22.59	.77	.45
Performance	.51	.05	.52	.07	.552	.58
Response Rate	.91	.08	.92	.06	.36	.73
Self-consciousness	3.40	1.70	2.59	1.84	1.48	.15
Interference	2.95	1.88	2.45	2.09	.81	.43

Figure 1. Change Detection Task

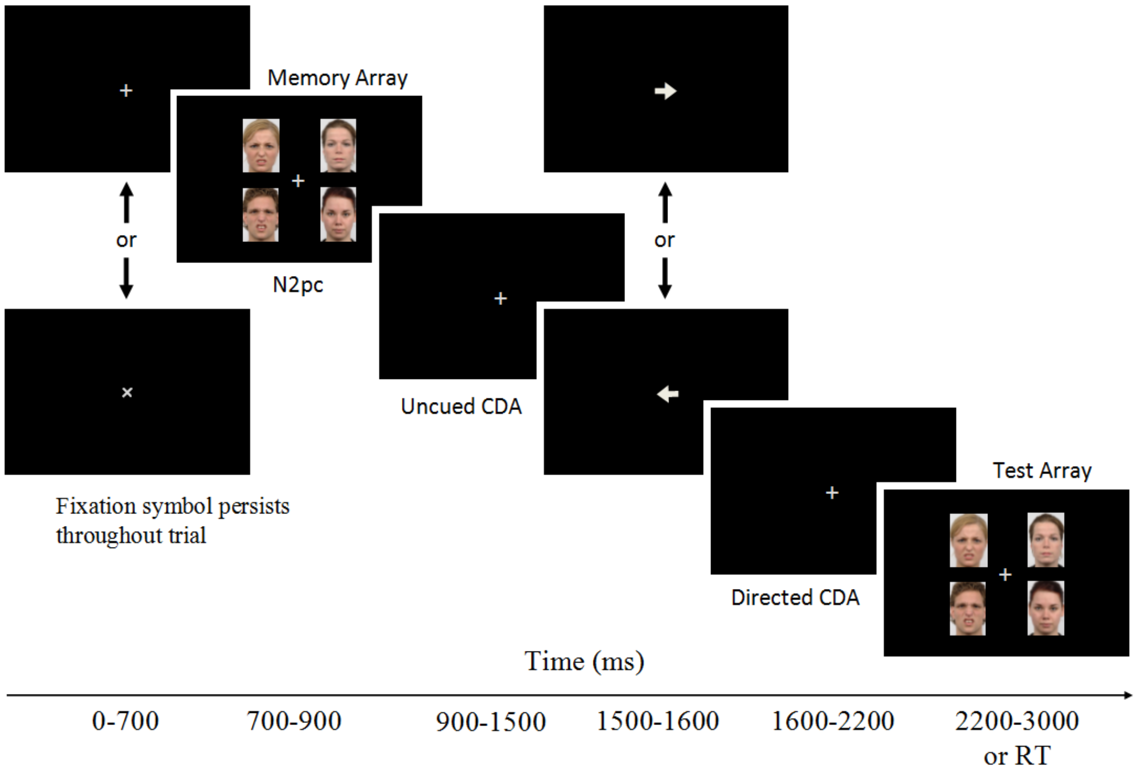


Figure 2. P1 event-locked to fixation onset

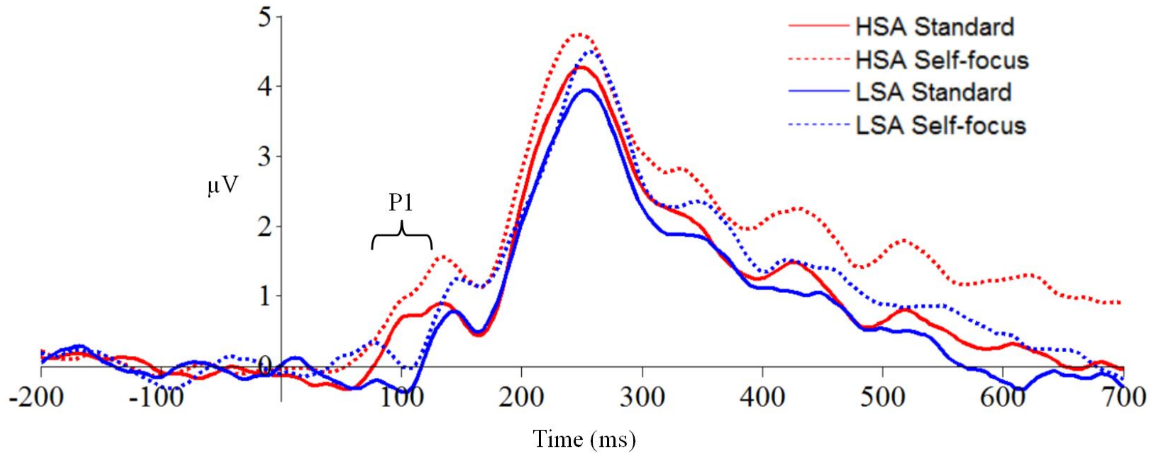


Figure 3. N2pc and uncued CDA event-locked to stimulus array onset

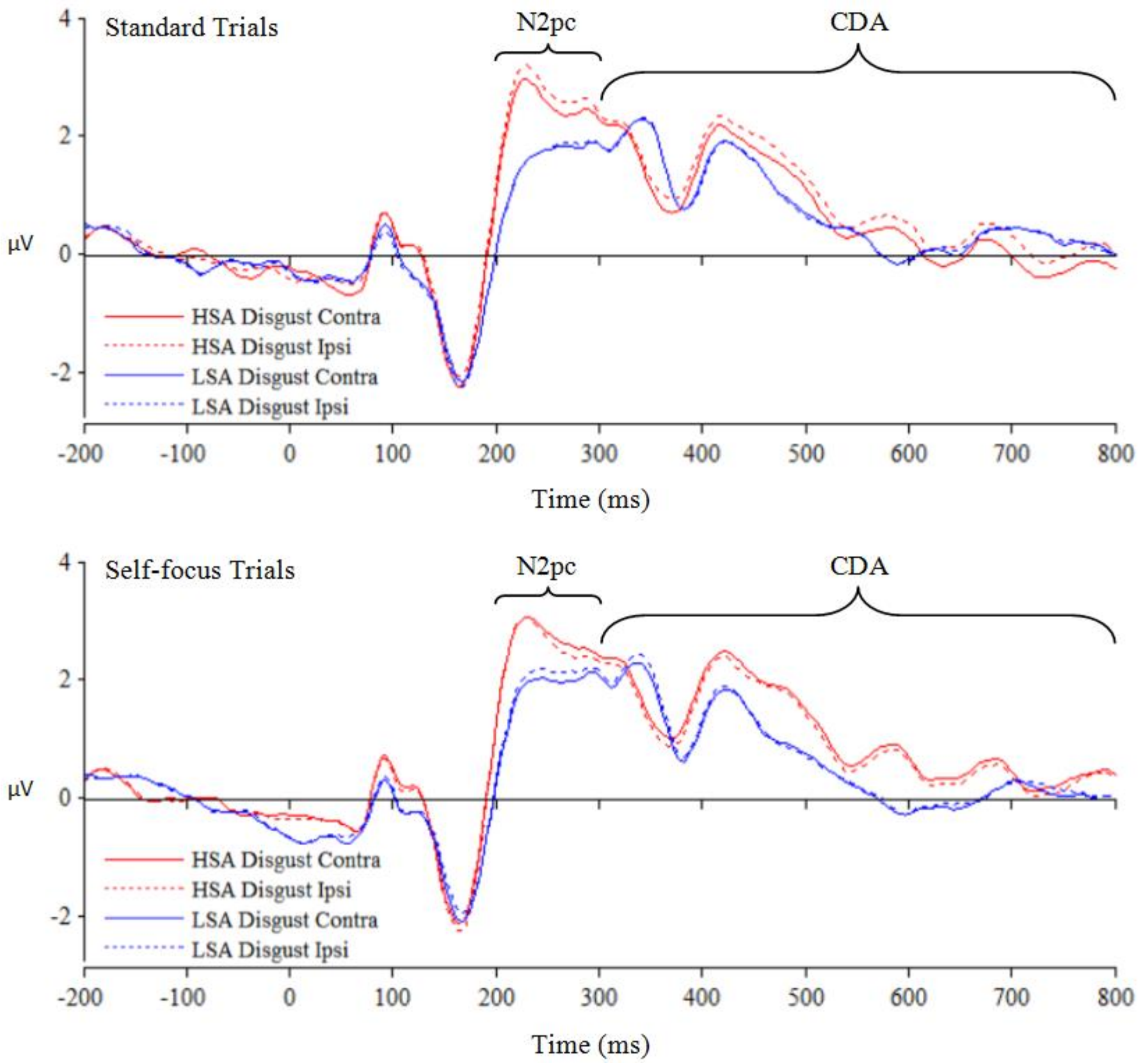
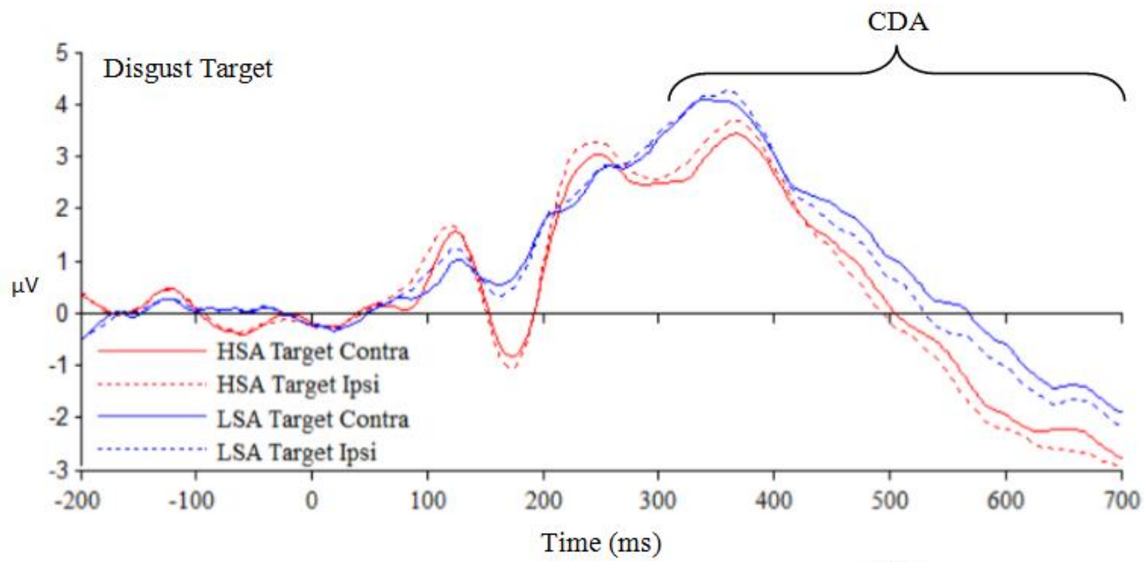


Figure 4. Cued CDA event-locked to arrow onset for standard trials



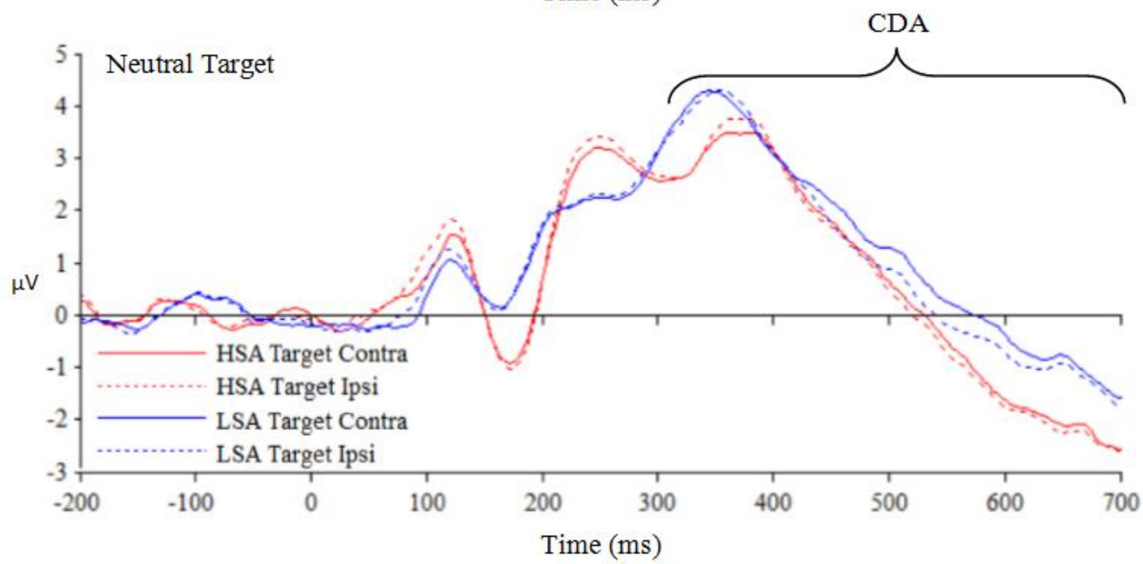
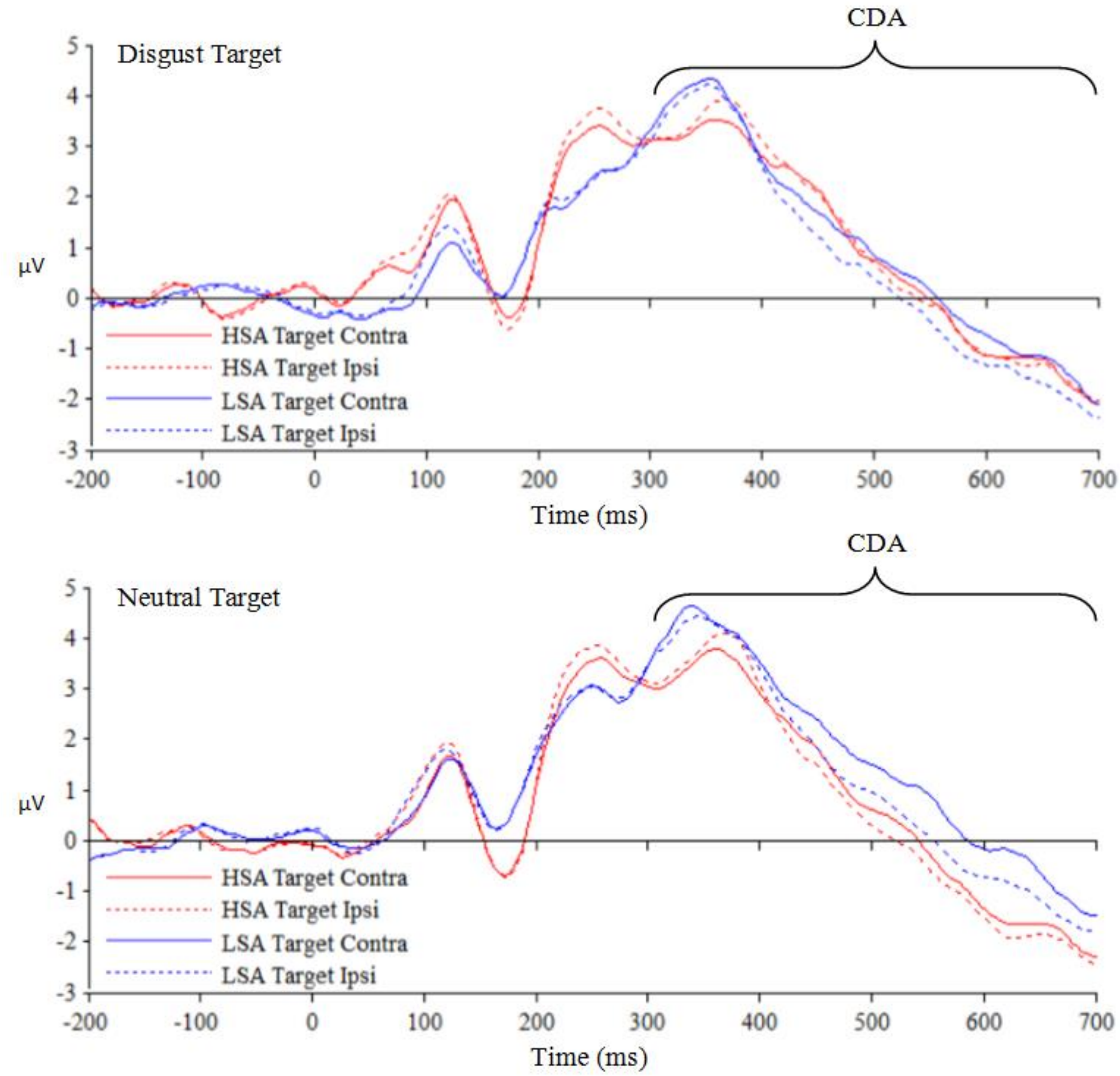


Figure 5. Cued CDA event-locked to arrow onset for self-focus trials



Demographic Questionnaire

What is your sex? ☐ 1= Male, 2=Female

1. Age: ☐☐ (years)

2. Year in School: ☐☐

3. Place of birth: ☐☐ (please use the following guide)

1 =	USA (mainland)	7 =	Asia, South Pacific
2 =	Puerto Rico	8 =	Africa
3 =	Dominican Republic	9 =	Europe
4 =	Other Caribbean	10 =	Other – Specify: ____________
5 =	Mexico		
6 =	Central/South America	99 =	Don't know.

Specify country of birth if it does not appear above: ____________________

5. What is your Ethnicity? ☐☐

1 = Hispanic/Latino
2 = Not Hispanic/Latino
3 = Don't know

6. What is your Race? ☐☐

1 =	White - not Latino	8 =	Mixed (White/Asian)
2 =	African-American	9 =	Mixed (other) - Specify:
3 =	Asian		____________
4 =	Native American		____________
5 =	Latino	10 =	Other – Specify:
6 =	Mixed (White/African-American)		____________
7 =	Mixed (White/Hispanic)	99 =	Don't know.

7. What is your religious affiliation? ☐☐

1 =	Catholic	6 =	None
2 =	Protestant	7 =	Other – Specify:
3 =	Jewish		____________
4 =	Jehovah's Witness		
5 =	Muslim	99 =	Don't know

8. In all, how many years have you lived in the U.S.? ☐☐

9. Occupational status: ☐☐

1 =	Employed full-time for pay	8 =	Unemployed <6 months, does not expect to work
2 =	Employed part-time for pay	9 =	Unemployed ≥6 months, does not expect to work
3 =	Homemaker	10 =	Laid off
4 =	Full-time student	11 =	Retired
5 =	Leave of absence for medical reasons (holding job, plans to return to work)	12 =	Other – Specify: ____________________
6 =	Unemployed <6 months, but expects to work	88 =	Not Applicable
7 =	Unemployed ≥6 months, but expects to work	99 =	Don't know

10. What is your first language (What language are you most comfortable in)?
____

11. Are you fluent in reading & writing English? ____________________

Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998)

For each question, please circle a number to indicate the degree to which you feel the statement is characteristic or true of you. The rating scale is as follows:

0 = Not at all characteristic or true of me
1 = Slightly characteristic or true of me
2 = Moderately characteristic or true of me
3 = Very characteristic or true of me
4 = Extremely characteristic or true of me

1. I get nervous if I have to speak with someone in authority (teacher, boss, etc.)	0	1	2	3	4
2. I have difficulty making eye-contact with others.	0	1	2	3	4
3. I become tense if I have to talk about myself or my feelings.	0	1	2	3	4
4. I find difficulty mixing comfortably with the people I work with.	0	1	2	3	4
5. I find it easy to make friends of my own age.	0	1	2	3	4
6. I tense-up if I meet an acquaintance on the street.	0	1	2	3	4
7. When mixing socially, I am uncomfortable.	0	1	2	3	4
8. I feel tense if I am alone with just one person.	0	1	2	3	4
9. I am at ease meeting people at parties, etc.	0	1	2	3	4
10. I have difficulty talking with other people.	0	1	2	3	4
11. I find it easy to think of things to talk about.	0	1	2	3	4
12. I worry about expressing myself in case I appear awkward.	0	1	2	3	4
13. I find it difficult to disagree with another's point of view.	0	1	2	3	4
14. I have difficulty talking to an attractive person of the opposite sex.	0	1	2	3	4
15. I find myself worrying that I won't know what to say in social situations.	0	1	2	3	4
16. I am nervous mixing with people I don't know well.	0	1	2	3	4
17. I feel I'll say something embarrassing when talking.	0	1	2	3	4
18. When mixing in a group, I find myself worrying I will be ignored.	0	1	2	3	4
19. I am tense mixing in a group.	0	1	2	3	4
20. I am unsure whether to greet someone I know only slightly.	0	1	2	3	4

Anticipatory Social Behaviors Questionnaire (ASBQ; Hinrichsen & Clark, 2003).

The following items ask you about behaviors, thoughts, and mental images that some people have prior to engaging in a social situation. Read each item below and select the option that best characterizes what you do prior to a social situation.

1	2	3	4
Never			Always

1. I think about similar situations in which I have failed in the past.	1	2	3	4
2. I try to think of everything that could happen.	1	2	3	4
3. I imagine the worst that could happen.	1	2	3	4
4. I go over in detail what might happen.	1	2	3	4
5. I try to picture how I will appear to others.	1	2	3	4
6. I try to plan what I am going to say.	1	2	3	4
7. I rehearse conversations in my mind.	1	2	3	4
8. I remind myself of things I should not do.	1	2	3	4
9. I think about ways in which I could put things right if I make a fool of myself.	1	2	3	4
10. I think about ways in which I could avoid having to face the situation.	1	2	3	4
11. I think about ways in which I could escape from the situation if it gets too embarrassing.	1	2	3	4
12. I make a conscious effort not to think about the situation.	1	2	3	4

Focus of Attention Questionnaire (Woody, 1996)

While interacting with others, some people focus on exactly what they are doing, while others find themselves focusing on other things such as feelings in their body, or objects in the room. We're interested in what you are focusing on **right now, as you wait for the social interaction to begin.** Please read the items below and indicate what you are concentrating on and thinking about.

Please use the following rating scale:

1	2	3	4	5
Not at all	Somewhat	Moderately	A lot	Totally

1. I am focusing on the other person's appearance or dress.	1	2	3	4	5
2. I am focusing on the features or conditions of the physical surroundings (e.g., appearance, temperature).	1	2	3	4	5
3. I am focusing on what I should say or do during the social interaction.	1	2	3	4	5
4. I am focusing on the impression I am going to make on my partner and/or the researchers.	1	2	3	4	5
5. I am focusing on how my interaction partner might feel about himself/herself.	1	2	3	4	5
6. I am focusing on what I will think of my interaction partner and/or what I think about the researchers.	1	2	3	4	5
7. I am focusing on my level of anxiety.	1	2	3	4	5
8. I am focusing on what the researchers are saying/doing.	1	2	3	4	5
9. I am focusing on my internal bodily reactions (e.g., heart rate, sweating).	1	2	3	4	5
10. I am focusing on past social failures.	1	2	3	4	5

Attentional Control Scale (ACS; Derryberry & Reed, 2002)

Here are some different ways that people can feel about working and concentrating. Please indicate how strongly each statement applies to you.

1 = Almost never 2 = Sometimes 3 = Often 4 = Always

1. It's very hard for me to concentrate on a difficult task when there are noises around.	1	2	3	4
2. When I need to concentrate and solve a problem, I have trouble focusing my attention.	1	2	3	4
3. When I am working hard on something, I still get distracted by events around me.	1	2	3	4
4. My concentration is good even if there is music in the room around me.	1	2	3	4
5. When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.	1	2	3	4
6. When I am reading or studying, I am easily distracted if there are people talking in the same room.	1	2	3	4
7. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.	1	2	3	4
8. I have a hard time concentrating when I'm excited about something.	1	2	3	4
9. When concentrating I ignore feelings of hunger or thirst.	1	2	3	4
10. I can quickly switch from one task to another.	1	2	3	4
11. It takes me a while to get really involved in a new task.	1	2	3	4
12. It is difficult for me to coordinate my attention between the listening and writing required when taking notes during lectures.	1	2	3	4
13. I can become interested in a new topic very quickly when I need to.	1	2	3	4
14. It is easy for me to read or write while I'm also talking on the phone.	1	2	3	4
15. I have trouble carrying on two conversations at once.	1	2	3	4
16. I have a hard time coming up with new ideas quickly.	1	2	3	4
17. After being interrupted or distracted, I can easily shift my attention back to what I was doing before.	1	2	3	4
18. When a distracting thought comes to mind, it is easy for me to shift my attention away from it.	1	2	3	4
19. It is easy for me to alternate between two different tasks.	1	2	3	4
20. It is hard for me to break from one way of thinking about something and look at it from another point of view.	1	2	3	4

Beck Depression Inventory – II (BDI-II; Beck et al., 1979; Beck & Steer, 1987)

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the **one statement** in each group that best describes the way you have been feeling during the **past two weeks, including today**. Circle the number beside the statement you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

1. Sadness
- 0. I do not feel sad.
- 1. I feel sad much of the time.
- 2. I am sad all the time.
- 3. I am so sad or unhappy that I can't stand it.

2. Pessimism
- 0 I am not discouraged about my future.
- 1 I feel more discouraged about my future that I used to be.
- 2 I do not expect things to work out for me.
- 3 I feel my future is hopeless and will only get worse.

3. Past Failure
- 0 I do not feel like a failure.
- 1 I have failed more than I should have.
- 2 As I look back, I see a lot of failures.
- 3 I feel I am a total failure as a person.

4. Loss of Pleasure
- 0 I get as much pleasure as I ever did from the things I enjoy.
- 1 I don't enjoy things as much as I used to.
- 2 I get very little pleasure from the things I used to enjoy.
- 3 I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings
- 0 I don't feel particularly guilty.
- 1 I feel guilty over many things I have done or should have done.
- 2 I feel quite guilty most of the time.
- 3 I feel guilty all of the time.

6. Punishment Feelings
- 0 I don't feel I am being punished.
- 1 I feel I may be punished.
- 2 I expect to be punished.
- 3 I feel I am being punished.

7. Self-Dislike
- 0 I feel the same about myself as ever.
- 1 I have lost confidence in myself.
- 2 I am disappointed in myself.
- 3 I dislike myself.

8. Self-Criticalness
- 0 I don't criticize or blame myself more than usual.
- 1 I am more critical of myself than I used to be.
- 2 I criticize myself for all of my faults.
- 3 I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes
- 0 I don't have any thoughts of killing myself.
- 1 I have thoughts of killing myself, but I would not carry them out.
- 2 I would like to kill myself.
- 3 I would kill myself if I had the chance.

10. Crying
- 0 I don't cry any more than I used to.
- 1 I cry more than I used to.
- 2 I cry over every little thing.
- 3 I feel like crying, but I can't.

11. Agitation

0 I am no more restless or wound up than usual.
1 I feel more restless or wound up than usual.
2 I am so restless or agitated that it's hard to stay still.
3 I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest

0 I have not lost interest in other people or activities.
1 I am less interested in other people or things than before.
2 I have lost most of my interest in other people or things.
3 It's hard to get interested in anything.

13. Indecisiveness

0 I make decisions about as well as ever.
1 I find it more difficult to make decisions than usual.
2 I have much greater difficulty in making decisions that I used to.
3 I have trouble making any decisions.

14. Worthlessness

0 I do not feel I am worthless.
1 I don't consider myself as worthwhile and useful as I used to.
2 I feel more worthless as compared to other people.
3 I feel utterly worthless.

15. Loss of Energy

0 I have as much energy as ever.
1 I have less energy than I used to have.
2 I don't have enough energy to do very much.
3 I don't have enough energy to do anything.

16. Changes in Sleeping Pattern

0 I have not experienced any change in my sleeping pattern.

1a I sleep somewhat more than usual
1b. I sleep somewhat less than usual.

2a I sleep a lot more than usual.
2b I sleep a lot less than usual

3a I sleep most of the day.
3b I wake up 1-2 hours early and can't get back to sleep.

17. Irritability

0 I am no more irritable than usual.
1 I am more irritable than usual.
2 I am much more irritable than usual.
3 I am irritable all the time.

18. Changes in Appetite

0 I have not experienced any change in my appetite.

1a My appetite is somewhat less than usual.
1b My appetite is somewhat greater than usual.

2a My appetite is much less than usual.
2b My appetite is much greater than usual.

3a I have no appetite at all.
3b I crave food all the time

19. Concentration Difficulty

0 I can concentrate as well as ever.
1 I can't concentrate as well as usual.
2 It's hard to keep my mind on anything for very long.
3 I find I can't concentrate on anything.

20. Tiredness or Fatigue

0 I am no more tired or fatigued than usual.
1 I get more tired or fatigued more easily than usual.
2 I am too tired or fatigued to do a lot of the things I used to do.
3 I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex

0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

Anxiety Sensitivity Index – 3 (ASI-3; Taylor et al., 2007)

Enter the number from the scale below that best describes how typical or characteristic each of the 18 items is of ***you***, putting the number next to the item. You should make your ratings in terms of how much you agree or disagree with the statement as a ***general*** description of yourself.

0 = very little   1 = a little   2 = some   3 = much   4 = very much

1. It is important for me not to appear nervous.	0	1	2	3	4
2. When I cannot keep my mind on a task, I worry that I might be going crazy.	0	1	2	3	4
3. It scares me when my heart beats rapidly.	0	1	2	3	4
4. When my stomach is upset, I worry that I might be seriously ill.	0	1	2	3	4
5. It scares me when I am unable to keep my mind on a task.	0	1	2	3	4
6. When I tremble in the presence of others, I fear what people might think of me.	0	1	2	3	4
7. When my chest feels tight, I get scared that I won't be able to breathe properly.	0	1	2	3	4
8. When I feel pain in my chest, I worry that I'm going to have a heart attack.	0	1	2	3	4
9. I worry that other people will notice my anxiety.	0	1	2	3	4
10. When I feel "spacey" or spaced out I worry that I may be mentally ill.	0	1	2	3	4
11. It scares me when I blush in front of people.	0	1	2	3	4
12. When I notice my heart skipping a beat, I worry that there is something seriously wrong with me.	0	1	2	3	4
13. When I begin to sweat in a social situation, I fear people will think negatively of me.	0	1	2	3	4
14. When my thoughts seem to speed up, I worry that I might be going crazy.	0	1	2	3	4
15. When my throat feels tight, I worry that I could choke to death.	0	1	2	3	4
16. When I have trouble thinking clearly, I worry that there is something wrong with me.	0	1	2	3	4
17. I think it would be horrible for me to faint in public.	0	1	2	3	4
18. When my mind goes blank, I worry there is something terribly wrong with me.	0	1	2	3	4

WAIS III Letter-Number Sequencing Subtest (Wechsler, 1997)*

Set Size	Trial	Item/ Response	Trial Score (0 or 1)	Item Score (0, 1, 2, or 3)
2	1	M-4 (4-M)		
	2	8-R (8-R)		
	3	D-3 (3-D)		
3	4	G-4-P (4-G-P)		
	5	E-2-M (2-E-M)		
	6	J-1-9 (1-9-J)		
4	7	T-7-E-5 (5-7-E-T)		
	8	X-1-L-4 (1-4-L-X)		
	9	7-V-2-T (2-7-T-V)		
5	10	6-F-4-P-2 (2-4-6-F-P)		
	11	G-2-C-7-W (2-7-C-G-W)		
	12	5-N-3-S-8 (3-5-8-N-S)		
6	13	B-3-L-6-N-1 (1-3-6-B-L-N)		
	14	Y-7-I-6-F-4 (4-6-7-F-I-Y)		
	15	6-F-8-C-1-U (1-6-8-C-F-U)		
7	16	R-3-D-1-X-6-L (1-3-6-D-L-R-X)		
	17	3-T-8-K-1-P-7 (1-3-7-8-K-P-T)		
	18	F-1-H-5-S-3-D (1-3-5-D-F-H-S)		
8	19	3-I-7-V-2-N-9-A (2-3-7-9-A-I-N-V)		
	20	D-1-S-7-C-6-M-3 (1-3-6-7-C-D-M-S)		
	21	7-E-2-T-5-Y-8-P (2-5-7-8-E-P-T-Y)		
		Total Raw Score (Maximum=21)		

*This test has been modified to preserve test security. The numbers and letters used are not those in the actual WAIS III.

VITA

Matthew Ryan Judah

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control
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Robberson Dissertation Fellowship – Oklahoma State University
Distinguished Graduate Fellowship – Oklahoma State University