THE NEURAL CORRELATES OF IMPAIRED ATTENTIONAL CONTROL IN SOCIAL ANXIETY: AN ERP STUDY

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CHAPTER I

INTRODUCTION

Cognitive models of social anxiety disorder (SAD; Clark & Wells, 1995; Rapee & Heimberg, 1997) describe mental processes which socially anxious individuals (HSAs) utilize in feared social situations. These processes broadly include three categories of information-processing biases (see Amir & Foa, 2001; Heinrichs and Hofmann, 2001 for a review): interpretation biases (see Hirsch & Clark, 2004 for a review), memory biases (see Morgan, 2010 for a review), and attentional biases. Interpretation biases occur as HSAs construe ambiguous social events to be more threatening. Memory biases in SAD include a tendency to recall negative events more easily and positive events with more difficulty. Attentional biases describe the preoccupation of mental resources by salient processes or stimuli, which in the case of SAD are those that indicate a high likelihood of negative evaluation. Attentional biases are of particular interest because they may generate the other information processing biases and interfere with behaviors that enable successful social interaction.

Because social fears are at the core of SAD, these individuals devote excessive attentional resources to determine whether they are being evaluated. This results in attentional biases including self-focused attention (Barlow, 2002; Clark & Wells, 1995; Rapee & Heimberg, 1997) and vigilance for environmental cues indicating negative evaluation (Barlow, 2002; Rapee & Heimberg, 1997; Schultz & Heimberg, 2008). Cognitive models of social anxiety predict that self-focused attention and hypervigilance should preoccupy attentional resources and potentially lead to impairment in behavioral processes dependent on attention. These theories, however, currently lack evidence supporting this prediction and specificity in describing how this might occur. Consequently, models focusing on the relationship between trait anxiety and performance may be useful to derive hypotheses to expand current knowledge of SAD. Specifically, attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007) proposes that anxiety depletes the resources of the central executive subsystem of working memory. Recently, predictions from this model have been tested in order to determine their generalizability for SAD (Amir & Bomyea, 2011; Wieser, Pauli, & Mühlberger, 2009); yet more extensive research is needed. Therefore, the purpose of this study was to test the implications of attentional control theory for SAD and thereby increase our understanding of the effects of social anxiety on the central executive and on processes that rely on working memory. This may help explicate the attentional processes that result from anxious symptomatology as well as their contribution to performance deficits. More specifically, this study tested whether social anxiety was associated with impaired executive control of attention.

Anxiety is postulated to impair performance across two levels (Eysenck & Calvo, 1992; Eysenck, et al, 2007): 1) processing efficiency, the quantity of cognitive resources allocated to the execution of a task, and 2) effectiveness, the proportion of correct to incorrect responses. These models propose that anxiety interferes ubiquitously with efficiency, whereas interference with effectiveness occurs only in situations in which anxiety consumes cognitive resources needed to perform optimally. Various methodologies have been utilized in order to assess processing efficiency, especially those measuring reaction time. Perhaps the most promising of these is the use of event-related potentials (ERPs), which measure the electrical activity associated with cognitive processes with high temporal resolution. Event-related potentials are electrophysiological wave forms generated as a result of neural processes. ERPs have been used to document attentional biases in trait anxiety (Carretié, Mercado, Hinojosa, Martín-Loeches, & Sotillo, 2004; Bar-Haim, Lamy, & Glickman, 2005), resulting impaired processing efficiency (Murray & Janelle, 2007; Dennis & Chen, 2008; Righi, Mecacci, & Viggiano, 2009), and activation of compensatory strategies used to maintain performance effectiveness (Dennis & Chen, 2008; Righi, et al., 2009). For example, Righi and colleagues (2009) found that high trait-anxious individuals recruit compensatory attentional effort, as indexed by larger N2 amplitudes, in order to maintain performance.

Thus, it is timely that these approaches be applied to examining the attentional processes of SAD. The hypothesis that attention biases may impair navigation of the social environment has important implications for understanding and treating SAD. Research has shown that social performance deficits can lead to rejection which in turn may maintain social fears (Meleshko & Alden, 1993; Voncken, Alden, Bögels, & Roelofs, 2008). Additionally, cognitive models (Clark & Wells, 1995; Rapee & Heimberg, 1997) suggest that memories of social rejection are used to shape how HSAs view themselves in social situations. Thus the interference of attentional biases with effective social behaviors may serve to perpetuate anxious symptomatology, and hence, may be an important area to target in treatment.

The current study utilized predictions from models of trait anxiety and attention to hypothesize that attentional bias in SAD, namely self-focused attention, would result in diminished processing efficiency. This was examined using a mixed antisaccade task in which subjects were required to perform cued saccades (ballistic eye movements) toward or away from stimuli appearing in their parafoveal vision. Self-focused attention was manipulated in 20% of the trials via a circle which appeared around the cue. Prior to the experiment, subjects were told that this indicated increased heart rate and that they should ignore it. Two ERP components event-locked to cue onset were examined: the CNV, a slow-wave fronto-central negativity peaking between 260 and 470 ms after cue onset which is associated with the recruitment of processing resources in response preparation, and the P3b, a positive parietal potential occurring 450-600 ms post-stimulus which is associated with stimulus probability and the attentional effort devoted to stimulus categorization (Luck, 2005; Polich, 2007). Previous research has linked CNV amplitude to the recruitment of effort to respond to an anticipated stimulus (see Rösler, Heil, & Röder, 1997). Similarly, increases in task difficulty have been shown to reduce P3b amplitude (Kok, 2001). Therefore, it was predicted that HSAs would have stronger CNV amplitudes than LSAs on all trials and that the CNV would emerge later. Further, P3b amplitude was expected to be diminished and to have a later onset for HSAs in the presence of threat. It was also predicted that HSAs would have later onset times for correct saccades.

CHAPTER II

REVIEW OF THE LITERATURE

Overview of Social Anxiety Disorder

Social anxiety disorder (SAD) is the most common of the anxiety disorders, and research estimates a 3-13% lifetime prevalence (APA, 2000; Jefferys, 1997). This disorder is characterized by excessive fear of being negatively evaluated in social and performance situations (APA, 2000). SAD also involves a desire to achieve closeness to others and the belief that one will be unable to do so (Alden, 2001; Clark & Wells, 1995). Anxious symptomatology causes impairment and distress in interpersonal and/or occupational functioning (APA, 2000). Broadly, social anxiety symptoms may be generalized to most social situations or circumscribed to specific ones (APA, 2000; Rapee & Heimberg, 1997). Symptoms also may manifest with a variety of idiographic characteristics, such as blushing and specific safety behaviors.

Cognitive Models of Social Anxiety Disorder

Cognitive approaches to understanding SAD have contributed an important framework for integrating empirical evidence. These models (Clark & Wells, 1995; Rapee & Heimberg, 1997) propose that individuals high in social anxiety (HSAs) fear being evaluated negatively by others and believe that this is likely to occur. As a result, cues in the environment which indicate the likelihood of evaluation from others are especially salient. HSAs focus attention on aspects of the self which they fear may catalyze this process. More specifically, they adopt an observer perspective of themselves, often exaggerating the conspicuousness of their negative features. Memories of past social experiences, as well as proprioceptive and physiological awareness, are used to inform this self-image and to make predictions about the likelihood of rejection. Secondly, HSAs exercise vigilance for stimuli in the environment that indicate the social evaluation which they fear (Rapee & Heimberg, 1997). Following the feared situation, social phobics tend to engage in post-event processing, typified by recall of the social situation and negative interpretations of the self's role in that situation (Clark & Wells, 1995; Rapee & Heimberg, 1997).

Cognitive models of SAD suggest that socially anxious individuals believe others to be fundamentally critical and evaluative of them (Clark, 2001; Clark & Wells, 1995; Rapee & Heimberg, 1997). Because socially anxious individuals place a premium upon being liked and accepted by others, beliefs that they will be negatively evaluated are particularly threatening to them. Various processes emerging from these beliefs result in anxious symptomatology. These may occur when feared social situations are encountered, when they are expected to occur, or afterward (Rapee & Heimberg, 1997).

Socially anxious individuals often utilize strategies to prevent behaviors that might lead to rejection by others. These strategies, known as safety behaviors, are classically exemplified in individuals who try to cover or turn away their faces out of fear that others will see them blushing. Safety behaviors may also include mental processes, such as planning what one will say in certain situations (Clark, 2001). Anxiety is maintained through safety behaviors because they are credited with the non-occurrence of social rejection, which in turn, reinforces these behaviors (Clark, 2001; Clark & Wells, 1995; Salkovskis, 1996; Wells, Clark, Salkovskis, & Ludgate, 1995). Further, certain safety behaviors may increase the likelihood of socially undesirable behaviors (Stevens et al., 2010) thus leading to further negative ruminations about the outcome of social experiences.

Attentional processes play a key role in cognitive models (Clark & Wells, 1995; Rapee & Heimberg, 1997). They propose that socially anxious individuals form a third-person mental image of their appearance and behavior as they believe it is perceived by others. This mental representation is not merely a mental photograph nor does it reflect how the individual views the self. Rather, it is an estimation of how they are perceived and evaluated by others. This involves self-focused attention, the direction of attentional resources toward the self. Additionally, socially anxious individuals monitor the environment for cues that they are being negatively evaluated by others (Rapee & Heimberg, 1997). This occurs via the allocation of attentional resources to sampling the external environment for indicators of potential threat.

Self-focused attention as described by cognitive models (Clark & Wells, 1995; Rapee & Heimberg, 1997) is particularly directed toward aspects of the self that are salient to fear of negative evaluation (i.e., negative facets of the self which might elicit negative judgments from others). The mental representation of the self is assumed to be one likely to receive negative evaluation from others. It is based on knowledge about one's appearance and previous social experiences, awareness of one's physiological arousal, and information gleaned from the environment, such as cues from others. Attention is focused on aspects of the self which may be judged negatively as these features are particularly salient. It is therefore likely to be negatively distorted. Further, external cues used to modify the mental image of the self, whether verbal or non-verbal, are often ambiguous and therefore easily distorted.

Socially anxious individuals then evaluate their performance and compare it to standards which they believe others expect of them. Based on the degree of discrepancy between these, estimations of the probability of negative evaluation are formed. Awareness of this perceived discrepancy increases anxiety about being negatively evaluated, which in turn, influences physiological responses as well as one's cognitions and behavior. This may escalate the discrepancy between current and ideal states as the estimation of one's current performance is negatively adjusted (Rapee & Heimberg, 1997).

Studies examining whether HSAs actually experience impaired social performance have achieved mixed results (Rapee & Heimberg, 1997). Although some research has demonstrated impaired performance across many functions (Twentyman & McFall, 1975), others have found impairment in some functions but not others (Arkowitz, Lichtenstein, McGovern, & Hines, 1975; Borkovec, Stone, O'Brien, & Kaloupek, 1974); whereas others have found no evidence of impairment (Burgio, Glass, & Merluzzi, 1981; Clark & Arkowitz, 1975; Rapee & Lim, 1992). Rapee and Heimberg (1997) propose that these disparate findings may occur because of the moderating role of the structure of the situation. It is interesting to note that these findings are anticipated by theories describing the relationship between anxiety and attention (e.g., Eysenck et al., 2007). These models predict such mixed results due to variability in attentional capacity and task difficulty.

Cognitive models suggest that social phobics process information dysfunctionally. These information-processing biases are thought to be maintained by the ambiguity of many social environments (Clark & Wells, 1995; Rapee & Heimberg, 1997). Because socially anxious individuals have a stronger motivation to know what others are thinking about them, they engage in self-evaluative thoughts informed by biased information-processing. These thoughts are further relied on as socially anxious individuals avoid behaviors typically used by normal individuals to disambiguate feedback from others (e.g., eye contact). Three main categories of biased information-processing occur in SAD. These are interpretation biases, memory biases, and attention biases (see Amir & Foa, 2001; Heinrichs & Hofmann, 2001 for a review). Attentional biases are of particular interest in understanding how anxiety may impair behavioral functioning because they influence the other two categories of biased cognition. Further, attentional biases are hypothesized to preoccupy attentional resources needed for effective behavior in anxious individuals (Eysneck et al, 2007).

Attentional Biases in SAD

Attentional biases in SAD include increased attention to the self and hypervigilance for threatening stimuli in the environment (Rapee & Heimberg, 1997). Although evidence uniformly supports self-focused attention in SAD, support for hypervigilance in SAD has met with mixed results (see Heinrichs & Hofmann, 2001). Evidence for hypervigilance has been challenged by evidence suggesting avoidance of threat (e.g., Foa & Kozak, 1986). This has resulted in the vigilance-avoidance hypothesis, which posits that HSAs are initially vigilant and engage in avoidance when threatening stimuli are detected (Mogg, Bradley, De Bono, & Painter, 1997). Research concerning attentional biases in SAD is discussed in detail below.

Self-focused Attention.

Extant research supports the hypothesis that social phobics typically engage in self-focused attention in threatening situations. Hackmann, Surawy, and Clark (1998) found that 77% of those in a social phobic sample reported third-person negative images of themselves, whereas only 10% of healthy controls reported such images. Self-focused attention has been examined mainly through correlational studies focusing of self-consciousness (e.g., Fenigstein, Scheier, & Buss, 1975) and through experimentally controlled social situations (e.g., Mellings & Alden, 2000). Correlational studies have found that social anxiety is correlated with high levels of public self-consciousness, attending to facets of the self that others might observe (Fenigstein, et al., 1975; Bruch & Heimberg, 1994) but not more private self-consciousness (Hope & Heimberg, 1988). Further, low self-ratings of physical attractiveness have been associated with shyness (Montgomery, Haimmerlie, & Edwards, 1991), although the ratings of others do not support actual lower physical attractiveness (Jones, Briggs, & Smith, 1986). Taken together, these findings suggest that shyness, which is currently thought to be mild social anxiety (Crome, Baillie, Slade, & Ruscio, 2010; Rapee & Heimberg, 1997), is associated with more negative feelings about one's own appearance than objectivity warrants.

Other studies have used experimental approaches to examine the association between social anxiety and negative images of the self. One commonly used approach is the dyadic interaction paradigm, also known as the getting acquainted paradigm. These studies have supported descriptions from cognitive models (Clark & Wells, 1995; Rapee

& Heimberg, 1997) that social phobics monitor their own physiology and use this information to construct negative images of the self which they visualize from an observer perspective (Mansell, Clark, & Ehlers, 2003; Papageorgiou & Wells, 2002; Wells, Clark, & Ahmad, 1998; Wells & Papageorgiou, 1999). Alden and Wallace (1995) examined performance self-ratings of men with SAD following a getting acquainted paradigm. They found that men with social phobia believed their anxiety was more visible to the interaction partner than it actually was. Social phobics also rated their own performance lower than did normal controls whether the interaction partner's approach was manipulated to be interpersonally warm or aloof. Other studies using this methodology have found that severity of social anxiety is positively correlated with self-reported self-focus (Hope, Heimberg, & Klein, 1990; Melchior & Cheek, 1990). Various studies have shown that awareness of internal somatic sensations is associated with feelings of being negatively evaluated (Mansell & Clark, 1999; McEwan & Devins, 1983; Mellings & Alden, 2000; Woody, 1996).

Additionally, psychophysiological approaches have been used to examine self-focused attention in SAD. Socially anxious individuals have been found to have higher levels of interoceptive awareness as indicated by awareness of heart rate when anticipating a speech compared to healthy controls (Stevens et al., 2010). Research also suggests that physiological sensations can increase self-focused attention. Experiments have demonstrated that increasing attention to physiological activity through exercise or false heart rate feedback increases self-focused attention (Fenigstein & Carver, 1978; Mansell et al., 2003; Papageorgiou & Wells, 2002; Wegner & Giuliano, 1980). Papageorgiou and Wells (2002) provided false feedback that the subject's heart rate had increased prior to a social interaction task. HSAs compared to LSAs were more sensitive to physiological feedback and showed increases in reported anxiety, negative interpersonal performance, and imagining themselves from an observer perspective. The increase of heart rate in the feedback, however, did not result in actual increased heart rate. Similarly, Mansell and colleagues (2003) misled participants to believe that a device applying a pulse to the fingertip indicated increased physiological response. They found that HSAs, but not LSAs, showed an internal attentional focus specific to social-evaluative threat. Other studies have demonstrated that increasing physiological arousal increases self-focused attention (Wegner & Giuliano, 1980; Fenigstein & Carver, 1978) and vice versa (Carver & Scheier, 1981; Scheier & Carver, 1983). This supports the prediction of cognitive models that physiological markers of anxiety are detected by socially anxious individuals and increase their level of self-focused attention, which in turn increases physiological arousal in a spiral toward more intense levels of self-focus and anxious physiology. This bi-directional effect may occur in social anxiety causing a self-perpetuating spiral that increases self-focused attention.

Hypervigilance

Extensive research supports Rapee and Heimberg's (1997) predictions about the role of externally oriented attention, also known as vigilance or hypervigilance, in SAD (see Cisler & Koster, 2010 for a brief review). However, the stimuli which elicit vigilance from HSAs vary between studies. Some studies suggest that HSAs are vigilant for emotional stimuli in general, whether emotional words (Asmundsen & Stein, 1994; Mattia, Heimberg, & Hope, 1993) or emotional faces (Garner, Mogg, & Bradley, 2006; Kolassa, Kolassa, Musial, & Miltner, 2007; Wieser, Pauli, & Mühlberger, 2009), whereas other research supports a bias exclusively for threatening stimuli, whether words (Amir & Bomyea, 2011; Grant & Beck, 2006; Hope, Rapee, Heimberg, & Dombeck, 1990; Maidenberg, Chen, Craske, Bohn, & Bystritsky, 1996; Mattia, et al., 1993; McNeil, et al., 1995; Pishyar, Harris, & Menzies, 2004; Vassilopoulos, 2005) or faces (Juth, Lundqvist, Karlsson, & Öhman, 2005, study 4; Kolassa et al., 2007; Kolassa & Miltner, 2006; Mogg & Bradley, 2002; Mogg, Philippot, & Bradley, 2004; Mühlberger, Wieser, Herrmann, Weyers, Tröger, & Pauli, 2009; Pishyar et al, 2004). Further, research suggests that these effects are significantly reduced following treatment of SAD (e.g., Mattia et al., 1993).

One of the most commonly used paradigms for examining attentional biases is the Emotional Stroop Task (see Williams, Mathews, & MacLeod, 1996 for a review). In this task, participants are asked to name the color of words which appear individually on a display. Biases in attention are measured via longer response latencies to color-naming emotionally threatening words compared to neutral or positive words. Several studies using this methodology have shown that socially anxious individuals take longer to name the color of words indicating social threat compared to other stimuli (Amir et al., 1996; Grant & Beck, 2006; Hope, et al., 1990; Maidenberg et al, 1996; Mattia et al., 1993; McNeil, et al., 1995).

Other experimental tasks (e.g., dot-probe tasks, visual search tasks, emotional saccade tasks) have found support for attentional biases in HSAs. Dot-probe tasks (MacLeod, Mathews, & Tata, 1986) present a series of paired stimuli that are adjacent to each other on a display. Following each pair of stimuli, a dot appears in one of the positions previously occupied by one of the two stimuli. Reaction time is measured as participants press a button to indicate the position in which the dot appeared. Stimuli are manipulated so that one indicates threat and the other is either positive or neutral, with attention biases being revealed by faster reaction times to dots appearing in the position where the threatening stimulus had been. Some dot-probe studies suggest attentional bias toward threat in clinical samples of SAD (e.g., Asmundson & Stein, 1994; Mogg et al., 2004; Mueller et al., 2009; Musa et al., 2003; Sposari & Rapee, 2007), although others have not (e.g., Horenstein & Segui, 1997). Studies using non-clinical samples also have achieved mixed results, with some studies confirming vigilance (e.g., Klumpp & Amir, 2009; Mogg & Bradley, 2002; Vassilopoulos, 2005) and others failing to do so (e.g., Pineles & Mineka, 2005).

Various explanations for these discrepant findings have been proposed. Schmulke (2005) reviewed the dot-probe paradigm and concluded that when used with non-clinical samples it yields low internal consistency and test-retest reliability. One reason for this may be that dot-probe tasks are confounded with post-perceptual processes, such as decision-making (Handy, Green, Klein, & Mangun, 2001; Mueller et al., 2009), a limitation which applies to studies using clinical samples as well. In order to resolve this problem, some recent studies utilizing the dot-probe technique have used event-related potentials (ERPs) in order to more accurately measure attentional processes (e.g., Mueller et al., 2009). Another possibility is that comorbid depression reduces hypervigilance in SAD, as a few studies suggest (Grant & Beck, 2006; Musa et al., 2003).

Perhaps the strongest explanation for the mixed dot-probe results of hypervigilance in SAD is its inability to discern between vigilance and later attentional confounds. Subjects that do not display speeded orientation toward a stimulus but have difficulty disengaging attention from it once it is detected would appear to be hypervigilant. Similarly, subjects demonstrating enhanced orientation toward a stimulus followed by avoidance would not still be attending to the stimulus location when the probe appeared, and would hence appear to lack hypervigilance. In order to resolve this problem, Koster and colleagues (2004) compared response times between congruent and incongruent trials as is typically done but also included trials containing a pair of neutral stimuli which were compared to the standard neutral-threat pairs. By comparing trials containing a threat cue with those that did not, they were able to rule out difficulty in disengaging attention as a potential cause for the observed effect. Future studies using this approach may contribute toward disentangling previous findings.

Visual search tasks (see Frischen, Eastwood, & Smilek, 2008 for a review) form another experimental category used to test for vigilance while controlling for the confound of difficulty in disengaging attention. In this paradigm participants are instructed to locate faces of a particular emotional valence that is unique in a field of other emotional faces. Visual search tasks have found that socially anxious individuals more quickly identify angry versus happy faces when scanning a field of neutral faces in which they are embedded (Gilboa-Schechtman, Foa, & Amir, 1999).

The emotional saccade paradigm is another experimental approach for examining hypervigilance. Emotional saccade tasks test the ability to control eye movements toward a target in the presence of a distracter while anti-saccade tasks require subjects to control eye gaze away from the emotional target. Reflexive shifts toward peripheral stimuli in the visual field indicate stimulus-driven attention. One benefit of this approach is that it can be used to investigate the effect of attentional biases on specific executive functions, such as inhibition and shifting. However, only a single study using this approach has been conducted to examine hypervigilance in SAD. This study found that socially anxious individuals preferentially attend to facial expressions in general compared to healthy controls (Wieser, Pauli, & Mühlberger, 2009). This supports the prediction of Rapee and Heimberg (1997) that socially anxious individuals are more attentionally reactive toward social stimuli. Further use of saccade paradigms to investigate attentional biases is discussed in a later section.

Currently, empirical findings regarding hypervigilance in SAD are not accounted for by cognitive models. Although many studies suggest that HSAs orient attention toward threatening stimuli, others suggest that they direct attention away from threat, a process known as avoidance (e.g., Mansell, Clark, Ehlers, & Chen, 1999). The vigilance-avoidance hypothesis emerged as an attempt to integrate these disparate findings (e.g., Mogg et al., 2004; Vassilopoulos, 2005) and predicts that HSAs automatically orient attention toward threat (vigilance) and subsequently direct attention away from threat (avoidance). To test this, manipulations of the dot-probe task have used varying stimulus onset asynchronies (SOAs), meaning that the elapsed presentation time of the stimuli is varied (usually at 500 and 1,250 ms). Some of these studies have found evidence for the hypothesized early, but not late, orientation toward threat, although no evidence was found that HSAs are more avoidant of threat cues at either SOA (e.g., Mogg et al., 2004; Pishyar et al., 2004; Vassilopoulos, 2005). Similarly, Wieser and colleagues (2009b) found that individuals with high fear of negative evaluation showed orientation toward emotional faces during the first second of exposure and avoidance from one to one and a half seconds after presentation. Using ERPs, Mueller and colleagues (2009) found enhanced early and dissipating late attentional processing of threat stimuli in social phobics. However, other evidence presents a major problem for the vigilance-avoidance hypothesis. Numerous studies suggest that HSAs have difficulty disengaging attention from threatening stimuli (Amir, Elias, Klumpp, & Przeworski, 2003; Buckner, Maner, & Schmidt, 2010; Moriya & Tanno, 2010, 2011). The quantity of evidence suggesting both avoidance of threat and difficulty in avoidance of threat has not yet been synthesized into a validated hypothesis. One possibility based on attentional control theory (Eysenck et al, 2007) is that working memory load moderates the relationship between early vigilance and later attentional biases.

Although extensive research supports attentional biases in SAD as described by cognitive models, research has not examined how these attention biases affect concurrent cognitive processes. In other words, research testing cognitive models has not yet probed whether self-focused attention and hypervigilance preoccupy limited cognitive resources so that they are offline for other important processes. Interestingly, Rapee and Heimberg (1997) describe concurrent self-focused attention and threat-detection in SAD as a "multiple-task paradigm" in which these processes and any concurrent executive process compete for limited attentional resources. Thus, individuals engaging in self-focused attention or hypervigilance should experience impairment on complex tasks, especially under high threat conditions. Nevertheless, cognitive models lack specificity in describing how this multiple-task paradigm impairs task performance. Therefore, research is needed to expand cognitive models to include specific predictions about how attention biases affect cognition and behavior. In order to develop reasonable hypotheses about mechanisms between attentional biases and performance, the current study draws from models that describe attention and performance in trait anxious individuals.

Theories of Trait Anxiety and Attention

Theories of trait anxiety and attention (e.g., Easterbrook, 1959; Eysenck & Calvo, 1992; Eysenck et al., 2007; Lavie, Hirst, De Fockert, & Viding, 2004; Sarason, 1988) posit that anxiety prompts the allocation of limited attentional resources toward processing threat-related information resulting in reduced cognitive resources for task-relevant processing. Among recent models, cognitive interference theory (Sarason, 1988) proposes that being preoccupied with the self is a core feature of anxiety and that this may distract attention from performing other behaviors. As attention is split between the performance of a given task and anxious thoughts, attentional resources devoted to the task are depleted. Sarason divides cognitive processes affected by self-preoccupation into three categories: attending to environmental cues, encoding and manipulating information, and constructing a behavioral response. However, the usefulness of Sarason's theory is limited by its lack of specificity for anxiety (i.e., self-preoccupation occurs in other cognitive-emotional states, such as anger). Further, cognitive interference theory lacks specific predictions about the cognitive systems affected by anxiety (Eysenck, 2010).

More recent models have borrowed from cognitive interference theory and other models to form more specific hypotheses. Pre-eminent among these models in terms of empirical support are the processing efficiency theory (Eysenck & Calvo, 1992) and the attentional control theory (Eysenck et al., 2007). Processing efficiency theory (PET; Eysenck & Calvo, 1992) was proposed in order to address the limitations of cognitive interference theory and is the first to suggest that anxiety impairs working memory specifically. It also defines specific ways in which this occurs by drawing a distinction between processing efficiency and effectiveness. Efficiency is defined as the quantity of cognitive resources devoted to achieve a certain level of performance and is usually measured as reaction time, whereas effectiveness is the quality of performance as measured by correct versus incorrect responses. PET predicts that worry associated with anxiety preoccupies, and thus interferes, with the phonological loop, the subsystem of working memory responsible for verbal rehearsal. This results in two processes. In the first, worry utilizes cognitive resources that would otherwise be used for the task at hand. Thus, the efficiency of working memory is diminished. Secondly, worry prompts the recruitment of additional cognitive resources to maintain effectiveness. If additional resources are not available because of high cognitive load, impaired efficiency gives way to reduced effectiveness (Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007). Thus, anxious individuals often utilize compensatory strategies in order to maintain performance at the cost of efficiency. Under sufficient cognitive load, however, these strategies are thought to be unable to prevent deficits in performance.

Attentional control theory (Eysenck et al, 2007) represents a revision of PET and maintains most of its predictions concerning processing efficiency and performance. However, the hypothesis that worry interferes with the phonological loop is replaced by the more empirically probable prediction that anxiety interferes with the central executive subsystem of working memory. The central executive manages attentional control, as illustrated by the restraint of a prevailing response in order to execute a subdominant response (Barrett, Tugade, & Engle, 2004; Ladouceur, Conway, & Dahl, 2010). ACT incorporates two basic attentional domains described by Corbetta and Shullman (2002), the goal-oriented attention system, which describes volitional top-down processes by which attention is dedicated to the achievement of a desired outcome, and stimulus-driven attention, an automatic bottom-up process which is characterized by monitoring of the self and/or the environment for salient stimuli. The stimulus-driven attention system is of particular interest to social anxiety research, because it includes both self-focused attention and hypervigilance. According to attentional control theory, anxious individuals allocate fewer attentional resources to goal-directed activity (i.e., successful social interaction for social phobics) while devoting more attention to stimulus-driven processes (i.e., self-focus and hypervigilance).

PET and ACT draw from Baddeley's (1974, 2001, 2003, 2010) model of working memory to describe how anxiety impairs attentional control. Working memory differs from short-term memory and long-term memory in that it relies on conscious effort in order to hold an object in memory (Engle, Tuholski, Laughlin, & Conway, 1999). Baddeley describes four subsystems, three of which involve temporal storage of information, and one which is associated with conscious control of the other systems. These subsystems are the phonological loop, which holds verbal-linguistic information, the visuospatial sketchpad, which holds mental images and orients them spatially, and the episodic buffer, which holds integrated information with both visual and verbal components and retrieves information from long term memory. The central executive manages the other three subsystems and controls attentional processes (Barrett et al., 2004).

The central executive has been subdivided by various researchers (e.g., Smith & Jonides, 1999; Miyake et al., 2000; Nigg, 2000). These models greatly overlap in their descriptions of central executive subfunctions; however, those proposed by Miyake and colleagues (2000; Friedman & Miyake, 2004) are preferred by attentional control theory because of their empirical basis. Miyake and colleagues (2000) used latent variable analysis to subdivide the control processes of the central executive into three basic functions: inhibition, characterized by the ability to intentionally restrain pre-potent stimulus-driven responses; shifting, which describes reallocation of attentional resources between tasks or mental representations; and updating, the refreshing of representations in working memory. ACT predicts that anxiety diminishes the aspects of the central executive most closely associated with attention, namely, inhibition and shifting (Eysenck et al., 2007). ACT hypothesizes a weaker relationship between anxiety and updating than between anxiety and the other control processes of the central executive (Eysenck et al., 2007).

Support for PET and ACT

Experiments testing the predictions of PET and ACT typically utilize a dual-task methodology wherein the efficiency (usually measured as reaction time) and effectiveness (usually measured as a ratio of accurate responses to errors) of individuals high in trait anxiety is compared to low anxious controls. The purpose of the secondary task is to manipulate cognitive load and overburden working memory capacity in order to evoke impairment in effectiveness on the primary task. The predictions of PET and ACT have been supported using this approach in a number of domains including athletic situations (see Wilson, 2008 for a review), driving simulations (Murray & Janelle, 2003, 2007), test-taking (Ng & Lee, 2010; Owens, Stevenson, Norgate, & Hadwin, 2008), and at a more basic level, working memory tasks (Eysenck, Payne, & Derakshan, 2005; Johnson & Gronlund, 2009).

Numerous studies have confirmed impairment in processing efficiency for high trait-anxious individuals. These include studies which index efficiency through self-report (Hadwin, Brogan, & Stevenson, 2005; Smith, Bellamy, Collins, & Newell, 2001), reaction time (Murray & Janelle, 2003; Williams, Vickers, & Rodrigues, 2002), event-related potentials (Ansari & Derakshan, 2011a, 2011b; Bar-Haim et al., 2005; Dennis & Chen, 2007; 2008; Murray & Janelle, 2007; Righi et al., 2009), event-related fMRI (Fales et al., 2008; Fales, Beccerril, Luking, & Barch, 2010), and EEG desynchronization (Savostyanov et al., 2009).

The saccade paradigm has been commonly used to test the predictions of attentional control theory. In this methodology, subjects are seated before a monitor and focus on a fixation cross in the center of the screen. When the fixation cross disappears, subjects are instructed to shift their visual focus to a peripheral cue as it appears on the monitor in what is known as the prosaccade task. This reflects activation of the stimulus-driven attentional system to orient overt attention toward a salient stimulus (i.e., vigilance). More interestingly, the antisaccade task requires the subject to look at a position on the screen opposite to the position where the cue appears. This task requires the individual to engage the goal-driven attentional system to inhibit the stimulus-driven system. Modifications of this paradigm using emotional peripheral stimuli have been used to confirm impaired attentional control in anxious individuals as indicated by prosaccadic errors (looking toward distracters on antisaccade trials) to positive, negative, and neutral facial expressions (e.g., Wieser, Pauli, & Mühlberger, 2009) and slower antisaccade latencies on correct responses, especially when using threatening cues

(Ansari, Derakshan, & Richards, 2008; Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009).

Many studies testing ACT utilize the probe technique in order to disentangle processing efficiency from effectiveness (Eysenck, 2010). This is a dual-task paradigm wherein subjects are instructed to perform an easy secondary task at intermittent cues if spare resources remain after prioritizing the primary task. The probe technique has been used to confirm impaired processing efficiency in high trait-anxious subjects as indexed by longer response times to auditory probes during a driving simulation (Murray & Janelle, 2003, 2007), while playing table tennis (Williams et al., 2002), and while performing basic working memory tasks (unpublished manuscript described in Eysenck, 2010). Other dual-task designs, such as that used by Eysenck and colleagues (2005), have supported ACT. High and low trait-anxious subjects completed a Corsi Block Task, in which participants observe and reproduce a sequence of taps on an arrangement of blocks, while performing a secondary task utilizing either the phonological loop, the visuospatial sketchpad, or the central executive. Impaired performance on the Corsi task was found to result in high-trait anxious individuals performing the concurrent central executive task only, thus supporting the predictions of ACT that anxiety specifically interferes with attentional control.

PET and ACT predict that individuals who are low in working memory capacity are most vulnerable to the impairing effects of anxiety. In contrast, two studies found that only individuals high in working memory capacity experienced performance deficits when anxiety was induced (Beilock & Carr, 2005; Beilock, Kulp, Holt, & Carr, 2004). The authors of these studies proposed that these individuals were more likely to rely upon strategies emphasizing attentional control, thus making them more vulnerable to anxiety's impairing effects upon this system. Addressing this discrepancy, Johnson and Gronlund (2009) showed that individuals with lower working memory capacity were more vulnerable to the detrimental effects of anxiety on task performance. They suggest that the discrepant results of Beilock and Carr (2005) and Beilock and colleagues (2004) may have occurred due to failure to account for trait anxiety and the use of tasks which allowed room for various cognitive strategies.

Attentional control theory predicts that the inhibition and shifting functions of the central executive are particularly vulnerable to anxiety (Eysenck et al., 2007). Recently, studies have investigated the effects of anxiety on these subfunctions of the central executive. Research testing the predictions of ACT regarding these processes is discussed below.

Inhibition

Various experimental designs have been used to test the effect of anxiety on inhibition. One of the most commonly used is the emotional Stroop task. This methodology has shown that clinical samples are slower to name the colors of words salient to their diagnostic status, indicating impairment in the ability to inhibit attention to task-irrelevant threat cues in order to efficiently process word content (see Williams, Mathews, & MacLeod, 1996 for a review).

The saccade paradigm has been identified as one of the most valid measures of inhibition (Miyake et al., 2000). Anti-saccade tasks are particularly useful in studies of the inhibition function because they require suppression of pre-potent responses (looking toward a stimulus) as well as subsequent initiation of a secondary action (directing gaze in the direction adjacent to the stimulus; Hutton & Ettinger, 2006). Studies using this approach have found that high trait anxious individuals compared to low trait anxious individuals show impaired processing efficiency as indexed by longer latencies on correct anti-saccades and that these latencies are even longer when threatening stimuli are used (Derakshan et al., 2009). These findings support the prediction that anxiety interferes with the executive ability to inhibit reflexive responses. Further, one study found that HSAs more quickly orient toward facial stimuli on prosaccade tasks and make more prosaccadic errors (looking toward the stimulus) on antisaccade tasks (Wieser, Pauli, & Mühlberger, 2009). This supports the use of ACT to generate specific predictions about the effects of social anxiety.

Currently, few studies have examined the predictions of ACT regarding the inhibition function using psychophysiological measures. One notable exception is a study using the stop-signal paradigm while measuring EEG desynchronization, changes in brain voltage indicating increased activation (Savostyanov et al., 2009). The stop-signal paradigm requires subjects to press a button to identify targets with a minority of these being followed by a signal indicating that subjects should not press any button, a process which requires the suppression of a pre-potent response. Inefficient inhibition was measured as increased EEG desynchronization, which indicates the increased use of cortical resources, in high trait anxious individuals versus low trait anxious controls. Two other studies have tested the effect of anxiety on inhibition using ERPs (Ansari & Derakshan, 2011a, 2011b). The first of these studies found that trait anxious subjects have greater negative ERP deflections than low trait anxious subjects immediately prior to successful antisaccades. Other research has suggested that this negative deflection is associated with the executive effort recruited to inhibit reflexive saccades (Everling, Matthews, & Flohr, 2001). Therefore, these results are interpreted to reflect the recruitment of more attentional resources to successfully inhibit stimulus-driven orientation toward the distracter. The second study used a mixed antisaccade task, which requires subjects to shift between prosaccades and antisaccades as cued by the color of the fixation cross. The researchers examined the amplitude of the contingent negative variation (CNV), an ERP waveform associated with anticipation of a cued stimulus and response preparation (see Bender, Resch, Weisbrod, & Oelkers-Ax, 2004; Rösler, Heil, & Röder, 1997). This study observed greater CNV amplitude in high trait anxious participants after cue offset compared to low trait-anxious individuals. This suggests that high trait-anxious individuals must exert greater attentional effort in order to maintain performance. Thus, both of these studies support impaired processing efficiency in high trait anxious individuals when engaging inhibitory processes.

Shifting

In comparison to studies testing the impairment of inhibition hypothesis, fewer studies have tested the predictions of ACT regarding the shifting function. Research predating ACT, however, provides an empirical basis for this hypothesis. For example, Goodwin and Sher (1992) found that anxiety predicted impaired efficiency and effectiveness for the Wisconsin Card Sorting Task. This task requires subjects to choose one of four cards that match a standard card on one of a number of shared features. Occasionally, the rule by which the cards match is changed, and subjects must determine the new rule and utilize it until it changes again. Although Miyake and colleagues (2000) identify this task as primarily utilizing the shifting function, it is not a high resolution measure of shifting effectiveness.

Other studies also suggest that the shifting process is affected by anxiety. In a test of simple mathematical calculations, Derakshan, Smyth, and Eysenck (2009) found that high levels of state anxiety predicted longer response times when participants were required to switch between mathematical operations. Other studies have utilized prospective memory tasks which test the ability to execute conditional responses to a delayed low-salience cue. These studies suggest that highly anxious individuals are more likely to make errors on prospective memory tasks (e.g., Cockburn & Smith, 1994; Harris & Cumming, 2003; Harris & Menzies, 1999).

Saccade tasks have been useful in the investigation of shifting as well. Ansari and colleagues (2008) compared performance on mixed (or cued) antisaccade/prosaccade trials to single-task prosaccade or antisaccade blocks. Mixed antisaccade tasks have been found to result in improvement in the antisaccade trials (e.g., Cherkasova, Manoach, Intriligator, & Barton, 2002). This is thought to occur because mixed-trial blocks provide updated instructions between trials via the cues, thus prompting attention toward the goal of the task. Single-task blocks give instructions only at the beginning of the block, thus the attention given to the goal is thought to diminish throughout the trial (De Jong, Berendsen, & Cools, 1999). As expected, Ansari and colleagues (2008) observed these counter-intuitive faster antisaccade latencies during mixed-trials in low anxious individuals. However, high anxious individuals did not perform faster on mixed-trial versus single-task antisaccades. This suggests that high-trait anxious individuals have fewer attentional resources available to attend to the goal during tasks requiring shifting.

Overall, this research supports the predictions of ACT that anxiety impairs the efficiency of shifting attention.

Event-related Potentials

Derakshan and Eysenck (2010) describe ideal tests measuring processing efficiency as possessing three main qualities: 1) a paradigm in which anxiety may be probed during the performance of a primary task, 2) non-significant or partialed out effects for performance effectiveness, and 3) documentation of brain activity. These criteria were used to inform the research design of the present study. The current study met the first criterion by including a task-irrelevant threat cue in 20% of trials. Processing efficiency and effectiveness were operationalized as latency and proportion of correct responses to incorrect responses, respectively. Additionally, ERPs were used to measure these constructs, thus providing a robust measure of the time at which cognitive processes occur and of the resources dedicated to these processes. Thus the use of ERPs met both the second and third criteria.

ERPs are electrical signals generated from the summation of cortical action potentials involved in specific cognitive processes. They are derived from electroencephalography (EEG), the electrical activity of the brain recorded at the scalp with a network of electrodes (usually 10-256). EEG measures changes in voltage between each active electrode and a reference electrode, usually located at the earlobe or mastoid. Because use of a single reference site exposes the voltage to contamination from activity near the reference, an average between two sites (e.g., both earlobes) is sometimes used as a reference (Luck, 2005). The EEG signal is amplified by three to five orders of magnitude because its amplitude is so low (< 100 µV). As is the case for all bioelectrical measures, the sampling rate of EEG is determined using the Nyquist Theorem, which states that the sampling rate should be at least twice the highest frequency in the signal. Setting the sampling rate too low can result in aliasing (i.e., sampling is insufficient to detect important voltage changes). In order to derive ERPs, the sampling rate is usually set between 200 and 1,000 Hz (i.e., 200 – 1,000 samples per second). As the EEG is sampled, the signal is filtered to remove frequencies that fall below or exceed voltage thresholds which neural signals are unlikely to reach. The lower threshold is typically set between .01 and .1 Hz, and the high cutoff is usually set between 15 and 100 Hz. Filtering requires great care as it can distort the latency of ERPs (Luck, unpublished manuscript; Luck, 2005).

ERPs are classified into two major categories. Those occurring soon after (e.g., < 300ms) the presentation of a stimulus are typically known as exogenous potentials. These early components are dependent on the stimulus characteristics, whereas later endogenous potentials are associated with executive functions (Luck, 2005; Näätänen, 1992).

Endogenous ERPs are frequently used to draw conclusions regarding conscious processing of the stimulus in processes such as recognition, categorization, response generation, and expectation violation (Luck, 2005). The most commonly studied of the endogenous ERPs is the P3b (also known as the P3 or P300), a positive spike occurring 450-600 ms after the stimulus. The P3b seems to be sensitive to local probability as indicated by enhanced amplitude at stimulus presentation for oddball stimuli. P3b amplitude is smaller and occurs later if a subject is uncertain about how to categorize a stimulus. This reflects the increased recruitment of attentional resources (Kok, 2001;

Polich, 2007). In dual-task paradigms, diminished attention to the secondary task is associated with reduced P3b amplitude to secondary task stimuli (Nash & Fernandez, 1996). For example, Murray and Janelle (2007) found that high state anxious individuals required to drive quickly in a driving simulator demonstrated reduced P3b amplitudes to probes in a secondary visual detection task. Although lap speed indicated that these individuals did not experience performance deficits, reduced P3b amplitudes reflected an increase in attentional demands for detecting visual probes in the secondary task.

Another useful endogenous component for studying processing efficiency is the CNV, a slow-wave sustained negative deflection that occurs between a warning and a target stimulus. (Luck, 2005). Studies examining vigilant attention have found that increased amplitude of the early contingent negative variation (CNV) occurred in both state and trait anxious subjects compared to normal controls when cued to expect negative stimuli (Carretié et al., 2004). More interestingly, the CNV has been used to test predictions of ACT. Ansari and Derakshan (2011a) found that greater CNV amplitudes were elicited in high trait anxious individuals compared to low anxious individuals while anticipating a cued stimulus.

There are several benefits to using ERPs. First, they are a relatively non-invasive technique for examining brain activity. Secondly, many ERPs do not require the subject to perform an overt behavior. In cases where a behavior is elicited, ERPs are a highly accurate measure of cognitive response time and are uncontaminated with variations in motor response time. ERPs give high temporal resolution for the occurrence of these processes. For these reasons, ERPs are commonly used to minimize measurement error in the study of cognitive processes, such as attention. Various studies testing attentional biases in SAD (Kolassa et al., 2007, 2009; Mueller et al., 2009; Sachs et al., 2004; van Peer, Spinhoven, & Roelofs, 2010;) and the effects of trait anxiety on attention (Ansari & Derakshan, 2011a, 2011b; Bar-Haim et al., 2005; Dennis & Chen, 2007, 2008; Murray & Janelle, 2007; Righi et al., 2009) have used ERPs to measure processing efficiency. Therefore, this study examined ERP components associated with the efficiency of attentional control. Specifically, the CNV and P3b components were examined. The CNV is of interest to the current study because it is a measure of executive resources recruited in anticipation of a cued stimulus. The P3b decreases and appears later as more attentional resources are devoted to a task (Kok, 2001). Therefore, attentional control theory predicts that the CNV should be larger and later and the P3b should be smaller and later for HSAs compared to LSAs in response to threat cues.

Current Study

Cognitive models of SAD predict that attentional biases (i.e., self-focused attention and hypervigilance) lead to performance deficits on any concurrently performed task (Barlow, 2002; Clark & Wells, 1995; Rapee & Heimberg, 1997; Schultz & Heimberg, 2008), yet they lack specificity regarding how this occurs. Attentional control theory (Eysenck, 2007) posits that anxious individuals maintain performance effectiveness by recruiting more attentional resources, thus diminishing processing efficiency. Although extensive research has been conducted to test the predictions of ACT for trait anxiety, relatively little has been done to examine the implications of this theory for specific anxiety disorders. Only two studies (Amir & Bomyea, 2011; Wieser, Pauli, & Mühlberger, 2009) have tested the predictions of ACT in a socially anxious sample. Thus, evidence that attentional control theory bears any relevance to SAD is currently insubstantial. Therefore, the current study aimed to expand knowledge about attentional biases in SAD by testing the predictions of ACT in a socially anxious sample. This study predicted that self-focused attention and hypervigilance in SAD would preoccupy attentional resources used by the inhibition and shifting functions of the central executive. It was predicted that this would result in reduced processing efficiency.

Secondly, the current study used methodology that advances basic knowledge regarding attentional control theory by utilizing psychophysiological measures, specifically ERPs. The majority of studies examining ACT have focused on behavioral measures, despite theoretical and empirical rationale to use approaches which more directly measure cognitive processes (Derakshan & Eysenck, 2010; Handy et al., 2001; Mueller et al., 2009). Therefore, a secondary goal of this study is to expand the psychophysiological literature testing attentional control theory.

The current study compared HSAs and LSAs in a mixed antisaccade task. Each subject executed cued prosaccades and antisaccades. The cue indicated social threat in 20% of trials. It was hypothesized that the CNV would be amplified, reflecting impaired processing efficiency, in HSAs compared to LSAs and that this would especially be the case during threat cues. Further, the current study predicted that the task in general would elicit diminished P3b amplitude and later P3b latency in HSAs, but not LSAs, indicating increased devotion of attentional resources, and that this effect would be more pronounced in the presence of threat cues. These predictions were made for both repeat (instructions maintained) antisaccade trials, indicating impaired efficiency of inhibition, and switch (instructions changed) prosaccade trials, reflecting impairment of the shifting function. Further, it was predicted that delayed saccade latencies would occur in HSAs and that this effect would be amplified during threatening trials.

CHAPTER III

METHODOLOGY

Participants

A minimum sample size of 15 subjects per group (HSA and LSA) was calculated based on the effect sizes of similar research designs (e.g., Ansari & Derakshan, 2011a) and Cohen's (1988) procedures to determine power. Participants were recruited using the undergraduate subject pool at a large Midwestern university. A measure of social anxiety (i.e., Social Interaction Anxiety Scale) was completed as part of a pre-screener. Those scoring at least one standard deviation above the mean (i.e., ≥ 30) or no greater than the mean (i.e., ≤ 19) for an undergraduate normalization sample (Mattick and Clarke, 1998) qualified for the study and were sent study invitations. The SIAS was readministered prior to the experiment, and cutoffs identical to the qualification criteria were used to divide participants into high (HSA) and low social anxiety (LSA) groups. The sample mean SIAS score was 26.31, with a means of 11.63 and 41.00 for the LSA and HSA groups, respectively.

Materials

Demographics Form. A self-report questionnaire was used to gather participant's demographic information, including age, sex, and education level.

Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1989). The SIAS is a 20-item measure that assesses the extent that individuals experience social fears when interacting with others. It is a widely used measure of social anxiety symptoms assessed on a five point scale with higher symptoms indicating higher levels of social anxiety. Internal consistency was high for the current study, $\alpha = .95$.

Center for Epidemiological Studies Scale for Depression (CES-D; Radloff, 1977). The CES-D is a 20-item questionnaire which assesses the frequency and intensity of common symptoms of depression over the previous week. Response options range from 0 = rarely or none of the time (less than 1 day), to 3 = most or all of the time (5-7 days). Cronbach's alpha was .90 for the current study.

Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, Fitzgerald, & Parkes,1982). The CFQ is a 25-item questionnaire with items rated on a 0 (never) to 4 (very often) Likert scale. It measures the frequency of commonly occurring minor cognitive errors in daily activities. For the current study, internal consistency was high, $\alpha = .93$.

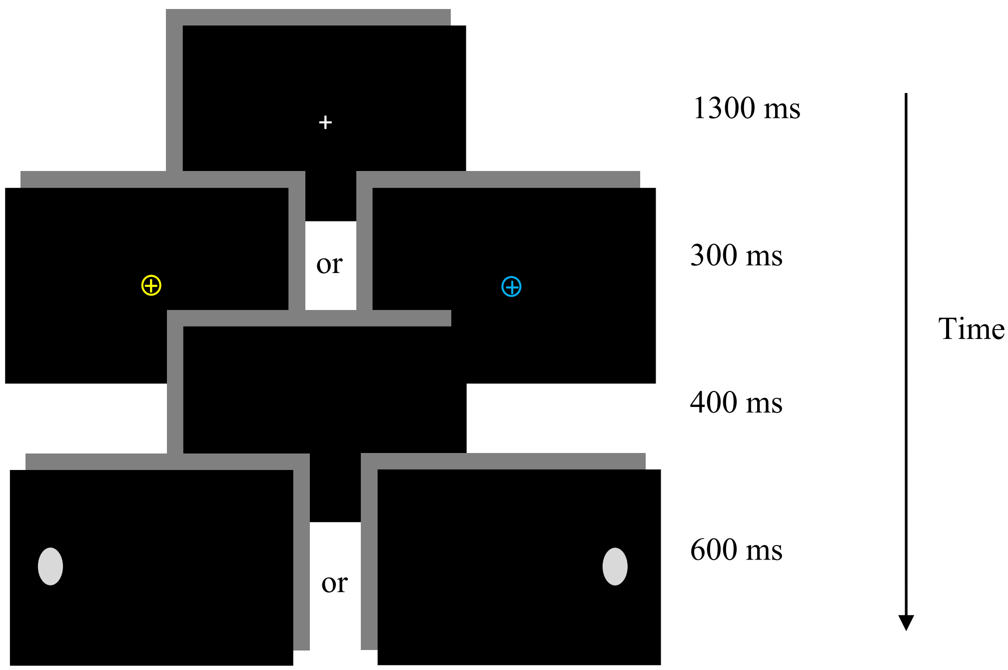
State-Trait Anxiety Inventory Form Y (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI consists of two 20-item measures of state and trait anxiety. Form Y is an updated version of the original measure (Spielberger, Gorsuch, & Lushene, 1970) and was developed in order to more validly measure the constructs. Cronbach's alpha was .92 for the Trait Subscale and .93 for the State Subscale in the current study.

Attentional Control Scale (ATTC; Derryberry & Reed, 2002). The attentional control scale is a 20-item measure of attentional control which measures two factors, attentional focusing and shifting. For the current study, only the total score was used as the subscales have not yet been validated. Each item is rated on a Likert scale ranging from 1 (almost never) to 4 (always). The scale had acceptable internal consistency in the current study, $\alpha = .82$

Procedure

Participants completed measures online prior to a mixed antisaccade task. Cue and stimulus latency and position were patterned after that used by Ansari and Derakshan (2011a, 2011b). Participants were then seated before a computer monitor, and an EEG cap, heart rate electrodes, and EOG electrodes were applied. Task instructions were communicated verbally before each block. Participants completed a mixed-antisaccade task consisting of four blocks with 100 trials each (see Fig. 1). Trials began with a fixation cross (+) indicating that the participant should focus visual attention on that location until the peripheral stimulus appeared (duration = 1300 ms). The fixation cross then changed color for 300 ms to serve as a cue. Response directives (prosaccade vs. antisaccade) were indicated by the color (yellow vs. blue) to which the fixation cross transformed (see Fig. 1). Participants were instructed beforehand to look at the oval that appeared after the cue for prosaccade directives and to look at the side of the monitor opposite the oval on antisaccade trials. Additionally, self-focused attention was manipulated using a color congruent circle which appeared around the fixation cross on 20% of trials. Prior to the first block, the experimenter told the subject that there was a glitch in the program which would cause a circle to appear around the fixation cross if the subject's heart rate increased. Following the cue, a blank screen appeared for 400 ms followed by the appearance of the stimulus, a grey oval, for a duration of 600 ms on either the left or right side of the screen. Intertrial intervals were varied between 300 ms, 600 ms, and 900 ms in order to prevent the elicitation of alpha waves in the EEG (Luck, 2005). In line with a similar study (Ansari & Derakshan, 2011a), participants completed four blocks consisting of approximately 100 trials each.

Fig.1 Mixed Antisaccade Task



Eye-tracking.

Horizontal saccades were measured following the conventions used by Ansari and Derakshan (2011a, 2011b), and saccade data was collected using BIOPAC Systems MP150 Hardware and AcqKnowledge Software. Electrodes were placed on the outer canthi of each eye. Horizontal electrooculogram (HEOG) voltage changes from baseline $> \pm 50$ µv were used to identify saccade initiation. Saccade direction was indicated by calculating the difference between left and right HEOG potentials. The signal was collected as DC without the use of high-pass filtering in order to prevent the attenuation of the signal. The standard procedure of eliminating initial saccades with latencies less than 80 ms or greater than 500 ms was followed (see Ansari & Derakshan, 2011a, 2011b; Fischer & Weber, 1993) in order to exclude pre-perceptual saccades and outliers. The current study predicted that initial saccade onset for correct trials would occur later in HSAs than LSAs and that this effect would be larger during threat manipulation. This prediction was based on previous research which observed delayed correct saccades in a sample with high trait anxiety, and interpreted this as impaired processing efficiency (Ansari & Derakshan, 2011).

Eye-movement analyses were restricted to the first saccade of each trial to occur after stimulus presentation. Saccades were identified using EOGUI (Hofmann, Schleicher, Galley, & Golz, 2011) a software designed to operate in MATLAB. Saccade onset was defined as the moment at which the velocity of eye-movement first exceeded 40 degrees per second. After this, a low-pass filter was used to identify plateaus in the signal indicative of saccades. Saccades were required to meet these and other standard criteria used by EOGUI (Hofmann et al., 2011).

Electroencephalography.

EEG data was collected using BIOPAC Systems MP150 Hardware and AcqKnowledge Software. An electrode cap (Electro-Cap International Inc.) was applied using the international 10-20 method for electrode placement. Data was collected from nine channels (FZ, F3, F4, CZ, C3, C4, PZ, P3, and P4) which were grounded by a mid-frontal electrode. All channels were referenced using the averaged mastoids technique (see Luck, 2005). Data were sampled at 250 Hz in accord with the Nyquist Theorem and filtered such that signals below .1 Hz and above 35 Hz were attenuated. Blinks were detected using an electrode below the right eye which shared a reference with the EEG electrodes.

Event-related potentials.

For the mixed antisaccade task, ERPs were event-locked to the onset of the imperative cue (i.e., fixation cross changes to blue or yellow). A digital TTL signal was sent from the PC presenting the stimulus to the PC recording the data in order to mark events. Data were epoched into 1000 ms segments beginning 200 ms before cue onset in order to obtain a baseline. Trials during which saccades occurred between cue offset and stimulus onset were thrown out in order to prevent the contamination of the ERPs with EMG associated with eye movement and ERPs associated with motion-perception (Luck, 2005; Luck & Girelli, 1998). Artifact detection, rejection, and data analyses were done using EEGLAB, version 9 (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2010).

Artifact rejection was done in four automated phases and a manual phase. Phase one involved the use of an automatic script in ERPLAB to reject trials on which voltage exceeded $\pm$100 µV. This rejected an average of .2% (SD = .9%) of trials. In the second phase, a moving window peak-to-peak threshold was used to identify and reject trials. This script identifies voltage changes exceeding 100 µV within a moving 200 ms window which progress through each trial in increments of 50 ms. This resulted in the rejection of an average of .3% (SD = 1.0%) of trials. The third phase consisted of blink rejection by a routine which examined the vEOG channel. This resulted in the rejection of 3.3% of trials on average (SD = 5.0%). Phase four consisted of a function which identified saccades on the hEOG channel and resulted in the removal of an average of .4% (*SD* = 1.4%) of trials. Finally, manual artifact detection was conducted on the remaining trials. Eye-blinks were suggested by sudden positive peaks restricted to the frontal channels and negative valleys in the vEOG, and these trials were removed. Trials on which hEOG activity suggested eye-movements were also removed, as were trials consisting of excessive noise or other artifacts. This resulted in the removal of an average of 8.9% of trials (*SD* = 8.5%).

Manipulation Check.

The self-focused attention manipulation was checked following the approach used by Papageorgiou and Wells (2002). The credibility of the heart rate feedback was evaluated by asking participants after the experiment if they could recall what the circle around the fixation cross indicated. Subjects also rated how much they believed that the heart rate feedback affected their self-consciousness and performance on a scale from 0 (not at all) to 7 (extremely).

Operational definitions.

Inhibition was operationally defined as the trials which required an antisaccade following a previous antisaccade trial (i.e., repeat saccade trials). Antisaccade trials following prosaccade trials were not included because they are confounded with a shift in instructions (i.e., shifting). Inefficiency of inhibition was measured as increased CNV amplitude in the inter-stimulus interval preceding inhibition trials. In line with previous research, greater CNV amplitude was interpreted as the recruitment of compensatory resources in order to maintain performance (see Ansari & Derakshan, 2011b). Inefficiency of inhibition was further operationalized as diminished P3b amplitude and delayed P3b onset (see Kok, 2001). Additionally, delayed onset of correct saccades was interpreted as impaired processing efficiency. Effectiveness of inhibition was measured as the ratio of correct to incorrect saccades on inhibition trials (see Ansari et al., 2008; Cherkasova et al., 2002).

Shifting was defined as prosaccade trials which followed antisaccade trials (i.e., switch prosaccade trials). By excluding switch antisaccade trials, shifting was not confounded with inhibition. The markers of inefficiency were identical to those described above for inhibition.

Analytical Approach

The current study used a mixed design with factors for social anxiety (HSA, LSA), self-focused attention condition (threat, no threat), executive function (shifting, inhibition) and measured multiple outcomes (CNV amplitude, CNV latency, P3b amplitude, P3b latency, initial saccade latency, and ration of correct to incorrect initial saccades). Therefore, the data was analyzed using a series of repeated measures factorial ANOVAs. Pairwise comparisons with Bonferroni adjustments were used to follow significant interactions.

Before analyzing the data, analyses were conducted to ensure that the assumptions of the statistical methods used were not violated. Assumptions for mixed designs include normality of the sampling distributions, equal variance between groups, and sphericity. Because reaction time data is characteristically skewed, saccades occurring more than 500 ms post-stimulus were excluded (see Ansari & Derakshan, 2011a). Further, nearly equal sample sizes in the levels of the independent variables, at least 20 df in the group error term, and the use of a two-tailed test are necessary to meet normality assumptions and were generally followed. Mauchly’s test was be used to evaluate sphericity, and

Greenhouse-Geisser corrections were used in all cases of violations of the sphericity assumption.

Effect size was calculated using eta squared following significant effects. In accord with statistical conventions, the current study considered .02 to be a small effect size, .13 to be medium, and .26 to be large.

Hypothesis 1

The current study hypothesized that HSAs would experience larger and later CNV amplitude during threatening cues and compared to LSAs. To examine this, independent 2 (Group: HSA, LSA) × 2 (Condition: Threat, Non-Threat) × 2 (Function: Shifting, Inhibition) × 6 (Site: FZ, F3, F4, CZ, C3, C4) mixed ANOVAs were used to examine amplitude and latency. In order to reduce the risk of spurious results, only frontal and central sites were examined, as the CNV maximizes at these sites (Luck, 2005).

Hypothesis 2

A diminished and later P3b was expected to occur in the presence of threat cues for the HSA group and compared to the LSAs across conditions. These predictions were tested using 2 (Group: HSA, LSA) × 2 (Condition: Threat, Non-Threat) × 2 (Function: Shifting, Inhibition) × 3 (Site: PZ, P3, P4) mixed ANOVAs to examine amplitude and latency. Only parietal sites were analyzed as the P3b maximizes there.

Hypothesis 3

It was predicted that HSAs would demonstrate increased saccade latency in the presence of threat cues. Further, it was predicted that this effect would be larger for inhibition versus shifting trials. A 2 (Group: HSA, LSA) × 2 (Condition: Threat, Non-

Threat) × 2 (Function: Shifting, Inhibition) mixed ANOVA was used to examine this hypothesis.

CHAPTER IV

FINDINGS

Sample Characteristics

Thirty-two (16 HSA, 16 LSA) participated comprised the final sample. Of those who participated, thirteen subjects were excluded because they did not meet the SIAS cutoff criteria for the groups (i.e., >19 and < 30). Six more were excluded because of high impedances (i.e., > 10 KΩ) or equipment malfunction. Of the thirty-two remaining participants, 14 were male (44%) and 18 were female (56%). The mean age of the sample was 19.78 (*SD* =1.29). Twenty-one participants identified as Caucasian (65.6%), 5 as African-American (15.6%), 2 as Asian (6.3%), 2 as Hispanic or Latina/o (6.3%), 1 as Native American (3.1%), and 1 as another race (3.1%). The HSA and LSA groups did not differ by sex, $\chi^2(1) = .51$, $p = .48$, age, $t(30) = .14$, $p = .89$, or ethnicity, $\chi^2(5) = 4.23$, $p = .52$. They did not differ on self-reported attentional control as measured by the ACS, but HSAs scored significantly higher on the CES-D, CFQ, and STAI (see Table 1).

Table 1: Comparison of HSA and LSA Groups on Self-Report Measures.

	HSA		*LSA*		*Comparisons*		
Variables	*M*	*SD*	*M*	*SD*	*t*	*df*	*p*
ACS	46.63	9.66	51.19	8.60	1.41	30	.169
CES-D	20.06	11.25	9.88	9.22	2.80	30	.009
CFQ	44.33	16.11	30.19	18.69	2.25	29	.032
STAI-S	29.20	11.23	19.69	9.57	2.55	29	.017
STAI-T	36.25	8.93	25.69	11.89	2.84	30	.008

Note. ACS = Attentional Control Scale; CES-D = Center for Epidemiological Studies Depression Scale; CFQ = Cognitive Failures Questionnaire; STAI-S & STAI-T = State-Trait Anxiety Inventory State and Trait Subscales, respectively

Manipulation Check

After the experiment, the majority of participants (30) were able to recall that the circles which appeared on some trials indicated increased heart rate. An independent samples *t*-test was conducted to evaluate differences between HSAs and LSAs in self-reported reactions to the heart rate feedback manipulation. There were significant differences between groups in self-report of self-consciousness, $t(28) = 2.77$, $p = .01$, and interference with task performance, $t(28) = 2.59$, $p = .015$. HSAs rated their self-consciousness during these trials to be higher ($M = 4.21$, $SD = 1.05$) than did LSAs ($M = 2.56$, $SD = 2.00$). Similarly, the HSA group reported that the appearance of the circle caused more interference with the ability to do the task ($M = 2.71$, $SD = 1.33$) compared to the LSA group ($M = 1.44$, $SD = 1.05$).

Eye-tracking

The ratio of correct to incorrect saccades for shifting and inhibition trials was significantly different, $\chi^2(2) = 26.05$, $p < .001$, with more errors being made on inhibition trials (37.83%) than on shifting trials (25.66%). The proportion of correct to incorrect saccades differed by group, $\chi^2(1) = 85.31$, $p < .001$, such that LSAs made significantly more errors (29.24%) than did HSAs (20.15%). There was not a significant difference between threat and non-threat trials, $\chi^2(1) = .36$, $p = .55$.

Mean correct onset times for each subject were calculated for inhibition and shifting trials. A 2 (Group [HSA, LSA]) × 2 (Condition [Threat, Non-Threat]) × 2 (Function [Inhibition, Shifting]) mixed ANOVA revealed a significant interaction between Function and Condition, $F(1,30) = 6.57$, $p = .016$, $\eta^2 = .18$. Simple effects analysis indicated that saccade onset was later for inhibition trials during threat (M = 212.98, SD = 27.54) compared to non-threat trials (M = 199.68, SD = 28.91; d = .49), $F(1,30) = 11.33$, $p = .002$, $\eta_p^2 = .27$. The main effect of function was significant, $F(1,30) = 61.13$, $p < .001$, $\eta^2 = .67$, such that saccade onset was later for inhibition trials (M = 206.33, SD = 27.10) than for shifting trials (M =165.67, SD = 21.72; d = 1.71). There also was a main effect for Group (see Fig. 2), $F(1,30) = 6.63$, $p = .015$, $\eta^2 = .18$, such that HSAs had significantly later saccade onset (M = 200.33, SD = 31.48) compared to LSAs (M = 171.67, SD = 31.48; d = .91).

Event-related Potentials

For the ERP analyses (see Fig. 3), only sites at which the P3b (parietal sites) and CNV (frontal and central sites) typically maximize were analyzed in order to reduce the risk of spurious results (Luck, 2005). In order to isolate the P3b, mean amplitude for each parietal site was calculated using a 300-500 ms post-cue window. A 2 (Group [HSA, LSA]) × 2 (Condition [Threat, Non-Threat]) × 2 (Function [Inhibition, Shifting]) × 3 (Site [PZ, P3, P4]) mixed ANOVA was used to evaluate hypothesis 1 regarding P3b amplitude. No interactions between the factors were significant. There was a significant main effect for Condition, $F(1,30) = 21.62$, $p < .001$, $\eta^2 = .42$, such that P3b amplitude for frequent non-threatening trials ($M = .70$, $SD = .32$) was lower compared to rare threat trials ($M = 1.27$, $SD = .59$). There also was a main effect for Function, $F(1,30) = 12.80$, $p < .001$, $\eta^2 = .30$, such that P3b amplitude was larger for shifting ($M = 1.17$, $SD = .51$) than for inhibition trials ($M = .80$, $SD = .40$). The main effect for Site was significant, $F(2,60) = 17.69$, $p < .001$, $\eta^2 = .37$. Pairwise comparisons showed that amplitude at site P3 ($M = .83$, $SD = .39$) was significantly smaller compared to PZ ($M = 1.09$, $SD = .42$) and P4 ($M = 1.03$, $SD = .46$), and that amplitude between these two sites was not significantly different ($p = .41$). As was hypothesized, there was a significant main effect for Group, $F(1,30) = 5.56$, $p = .025$, $\eta^2 = .16$, such that HSAs ($M = .74$, $SD = .58$) had lower P3b amplitudes compared to LSAs ($M = 1.23$, $SD = .58$).

Fifty percent fractional area latency was used to assess relative latency differences while minimizing the influence of noise (Luck, 2005). Negative values were zeroed to prevent negative components from overlapping with the windowing period. This resulted in three subjects (2 LSA, 1 HSA) lacking a clear P3b waveform for one or more trial types, and they were thus removed from these analyses. A 2 (Group [HSA, LSA]) × 2 (Condition [Threat, Non-Threat]) × 2 (Function [Inhibition, Shifting]) × 3 (Site [PZ, P3, P4]) mixed ANOVA was used to evaluate latency differences. There was a significant interaction between Group and Condition, $F(1,27) = 8.63$, $p = .007$, $\eta^2 = .24$. Simple effects analysis revealed that, as hypothesized, HSAs had later P3b onset for threat trials ($M = 397.59$, $SD = 24.00$) compared to non-threat trials ($M = 383.79$, $SD = 21.10$), $F(1,27) = 5.43$, $p = .028$, $\eta_p^2 = .17$, although there were no differences for LSAs ($p = .08$).

The interaction of Condition and Site also was significant, $F(1.6,42.3) = 4.32$, $p = .03$. However, no simple effects were significant after applying Bonferroni adjustments. There were no other significant effects.

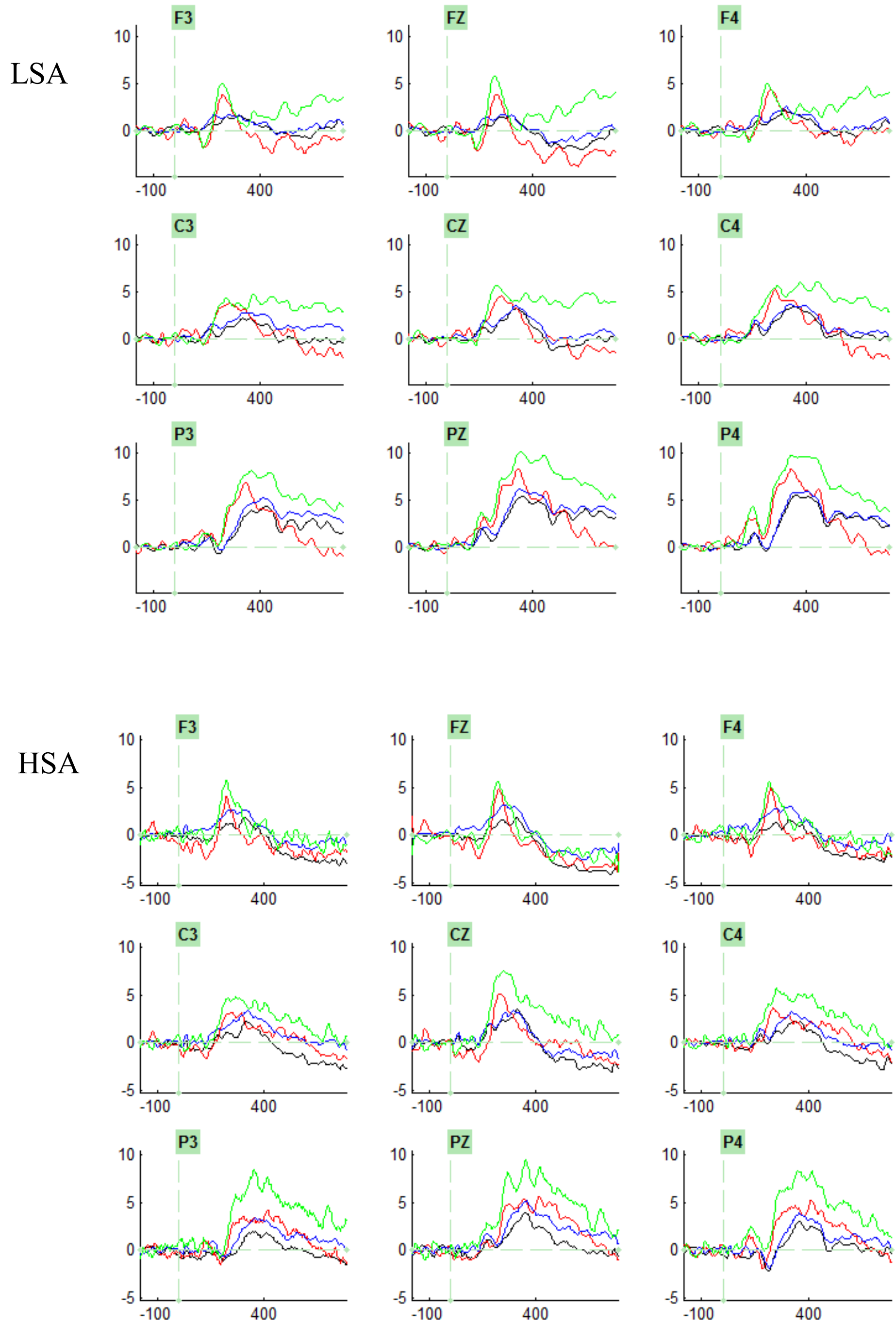
In order to isolate the CNV, the data was initially planned to be windowed around the interval between cue offset and 100 ms after stimulus presentation (see Ansari & Derakshan, 2011a). An examination of waveform plots showed that negative shifts were in progress as long as 100 ms post cue offset. In order to prevent contamination of the CNV by this shift, the data were windowed 100-400 ms post cue offset.

A 2 (Group [HSA, LSA]) × 2 (Condition [Threat, Non-Threat]) × 2 (Function [Inhibition, Shifting]) × 6 (Site [FZ, F3, F4, CZ, C3, C4]) mixed ANOVA was used to evaluate the hypothesis that HSAs would show stronger CNV potentiation. There was a significant three-way interaction between Group, Condition, and Function, $F(1,54) = 6.23$, $p = .018$, $\eta^2 = .17$. Simple effects analysis revealed that the HSA group ($M = -2.39$, $SD = 2.84$) had greater negativity compared to the LSA group ($M = .16$, $SD = 2.84$) for non-threat inhibition trials, $F(1,30) = 6.47$, $p = .016$, $\eta_p^2 = .18$. The three-way interaction between Condition, Function, and Site also was significant, $F(5,54) = 3.72$, $p = .003$, $\eta^2 = .11$. Multivariate simple effects analysis suggested that negativity at FZ ($M = -2.19$, $SD = 2.47$) was significantly larger compared to the other frontal sites, F3 ($M = -1.11$, $SD = 2.29$) and F4 ($M = -.87$, $SD = 2.40$) as well as C4 ($M = -.34$, $SD = 1.91$) for non-threat inhibition trials, $F(5,26) = 9.37$, $p < .001$, $\eta_p^2 = .64$. For non-threat shifting trials, FZ ($M = -.17$, $SD = .54$) was significantly more negative compared to the peripheral central sites C3 ($M = .18$, $SD = .42$) and C4 ($M = .16$, $SD = .44$), $F(5,26) = 9.00$, $p < .001$, $\eta_p^2 = .63$. For threat inhibition trials, negative amplitude was significantly greater at FZ ($M = -.43$, *SD* = .69) compared to F4 (*M* = -.06, *SD* = .75), C4 (*M* = .02, *SD* = .67), and C3 (*M* = -.01, *SD* = .61), $F(5,26) = 6.58$, $p < .001$, $\eta_p^2 = .56$. Potentials during threat shifting trials were lower at frontal sites FZ (*M* = .47, *SD* = 5.28), F4 (*M* = 1.18, *SD* = 5.09) and F3 (*M* = .86, *SD* = 4.90) compared to C4 (*M* = 3.04, *SD* = 4.59), $F(5,26) = 7.45$, $p < .001$, $\eta_p^2 = .59$. There also was a significant Threat by Site interaction, $F(5,84.17) = 4.02$, $p = .012$, but this was not probed given that these factors also interacted with Function. Similarly, the significant interaction between Function and Site was not probed, $F(5,86) = 4.64$, $p = .005$. There was a main effect for Condition, $F(1,30) = 4.63$, $p = .04$, $\eta^2 = .13$, indicating that greater negativity was associated with non-threat trials (*M* = -.55, *SD* = 1.08) compared to threat trials (*M* = .83, *SD* = 2.57). The main effect of Function was significant, $F(1,30) = 6.83$, $p = .014$, $\eta^2 = .19$, suggesting that negativity was greater for inhibition trials (*M* = -.63, *SD* = 1.12) than for shifting trials (*M* = .91, *SD* = 2.44). There also were significant differences between the electrode sites, $F(5,63) = 5.89$, $p = .004$, $\eta_p^2 = .16$. Multiple pairwise comparisons revealed that the frontal midline site FZ (*M* = -.58, *SD* = 1.75) was more negative compared to frontal peripheral sites F3 (*M* = -.11, *SD* = 1.64) and F4 (*M* = .07, *SD* = 1.64), as well as the central peripheral sites, C3 (*M* = .41, *SD* = .1.40) and C4 (*M* = .72, *SD* = 1.42). Frontal compared to central negativity was also more pronounced on both sides of the scalp. Amplitude at CZ did not differ significantly from other sites. Thus, negativity was maximized frontocentrally, which is consistent with CNV activity. Finally, there was a main effect for Group, $F(1,30) = 4.87$, $p = .035$, $\eta^2 = .14$, such that HSAs had a significantly larger negative potentiation (*M* = -.69, *SD* = 2.12) compared to LSAs (*M* = .97, *SD* = 2.12).

Fractional area latency analyses could not be conducted to isolate CNV latency because the CNV lasted beyond the data collection window in most cases. Additionally, the CNV shares several properties with the LRP which make onset calculation difficult, namely, the CNV emerges gradually and is characterized by noisy oscillations which are relatively long-lasting compared to most other ERPs (Miller, Patterson, & Ulrich, 1998). Therefore, CNV latency was measured using 50% fractional negative peak latency between 250 and 800 ms. Miller and colleagues (1998) used jackknifing to assess this method for estimating the LRP, a similar slow-wave potential, and found that it provided accurate estimates of waveform onset in most cases.

In order to evaluate CNV onset differences, a 2 (Group [HSA, LSA]) × 2 (Condition [Threat, Non-Threat]) × 2 (Function [Inhibition, Shifting]) × 6 (Site [FZ, F3, F4, CZ, C3, C4]) mixed ANOVA was conducted. There was a significant three-way interaction between Group, Condition, and Function, $F(1,30) = 10.67$, $p = .003$, $\eta^2 = .26$. Simple effects analysis revealed that, as hypothesized, HSAs showed significantly later CNV onset ($M = 603.74$, $SD = 96.56$) than did LSAs ($M = 454.87$, $SD = 96.56$) for shifting trials during threat, $F(1,30) = 19.01$, $p < .001$, $\eta_p^2 = .39$. The interaction of Group and Function was significant, $F(1,30) = 4.94$, $p = .034$, $\eta^2 = .14$, and simple effects analysis suggested that HSAs had significantly later CNV onset times for shifting trials ($M = 569.80$, $SD = 59.69$) compared to LSAs ($M = 487.94$, $SD = 59.69$), $F(1,30) = 15.05$, $p < .001$, $\eta_p^2 = .33$. The interaction of Function and Site was significant, $F(4.5,134.1) = 3.10$, $p = .01$, $\eta^2 = .09$. Multivariate simple effects analysis revealed differences between sites for inhibition trials, $F(5,26) = 6.69$, $p < .001$, $\eta_p^2 = .56$, such that CNV onset was slower at FZ ($M = 574.89$, $SD = 67.32$) compared to F3 ($M = 501.08$, $SD = 65.4$) and that it was slower at C4 (M = 589.11, SD = 75.74) compared to F3 and CZ (M = 518.90, SD = 98.48). There was a main effect for Site, $F(3.8,114.9) = 3.63$, $p = .009$, $\eta^2 = .11$. Pairwise comparisons revealed that CNV onset was significantly faster at F3 (M = 511.29, SD = 54.60) compared to C4 (M = 570.48, SD = 62.68). Finally, there was a main effect for Group, $F(1,30) = 5.42$, $p = .027$, $\eta^2 = .15$, such that onset of CNV was significantly later for HSAs (M = 562.04, SD = 63.08) compared to LSAs (M = 510.14, SD = 63.08).

Fig 2: Grand Averaged ERPs



Note: FZ filtered at 30 Hz for figure only. Voltage is shown in μV. Time is in ms.

CHAPTER V

CONCLUSION

The goal of the current study was to test the joint predictions of attentional control theory and cognitive models of social anxiety in a socially anxious sample. Overall, the findings supported the hypotheses and suggested impaired processing efficiency in the socially anxious group compared to the non-anxious control group. The socially anxious group showed impaired efficiency of attentional control as indexed by later onset of saccades for both inhibition and shifting trials, delayed P3b onset during threat compared to non-threat trials and delayed CNV onset compared to controls. This suggested that stimulus categorization and initiation of response preparation were delayed (Luck, 2005; Rösler et al., 1997). Reduced P3b amplitude across trial types and greater CNV amplitude compared to controls suggested that HSAs exercised more cognitive effort to categorize stimuli and prepare a saccadic response (Ansari & Derakshan, 2011a; Kok, 2001; Rösler et al., 1997). Interestingly, HSAs made fewer errors on inhibition and shifting trials, suggesting that they were able to maintain performance despite costs to processing efficiency. These findings are largely consistent with similar tests of attentional control theory in trait anxious individuals (Ansari & Derakshan, 2011a; b;

Murray & Janelle, 2007), and support the applicability of this theory for generating predictions about social anxiety.

Variations of the antisaccade task have been used extensively in order to assess attentional control (Ansari et al., 2008; Everling et al., 2001; Derakshan et al., 2009). Previous studies have defined inhibition as antisaccade trials and shifting as switch trials (e.g., Ansari & Derakshan, 2011a; b). However, this approach confounds the two processes by including switch antisaccade trials in measuring inhibition. A review of the literature suggests that the operational definitions used for inhibition and shifting in the current study are novel. Specifically, inhibition was defined as repeat antisaccade trials, and shifting was defined as switch prosaccade trials. This approach allowed for orthogonal definitions. The results suggested differences between these functions, with inhibition trials (compared to shifting) resulting in later onset of correct saccades, diminished P3b amplitude, greater CNV amplitude, and later CNV onset, all of which suggest that this task places more demands on the central executive. This is in line with previous studies which have found antisaccade trials to be more demanding than prosaccade trials (Ansari & Derakshan, 2011a; b). Additional research is needed in order to further evaluate this approach to operationalizing the mixed-antisaccade task.

The results of the current study provide support for the predictions of ACT regarding shifting and inhibition in line with the recommendations of Derakshan and Eysenck (2010) that such studies include manipulation of anxiety, discrimination between performance effectiveness and efficiency, and documentation of neural activity. Previous research has provided evidence that anxiety interferes with the efficiency of inhibition (Derakshan et al., 2009; Wieser et al., 2009a), but fewer studies have documented this effect for shifting. The current study found evidence that social anxiety impairs efficiency for both of these functions. These effects were found despite increased performance (i.e., correct trials) among HSAs. This is consistent with ACT, which posits that anxiety prompts the recruitment of attentional resources to maintain performance. The results contribute to and expand this growing literature.

The current study also provides evidence in support of cognitive theories of social anxiety and provides data which may extend these models (Clark & Wells, 1995; Rapee & Heimberg, 1997). These models broadly predict that self-focused attention utilizes attentional resources, thus increasing cognitive demands. However, they provide little detail concerning the effects of this process or the mechanisms by which it happens. The current study is the third (see Amir & Bomyea, 2011; Wieser et al., 2009a) to test the application of attentional control theory to address this gap. The findings support an integrated theory in which self-focused attention results in impaired attentional control. Specifically, HSAs showed slowed inhibition and shifting compared to low anxious controls. At the level of neural processes, they showed more effortful allocation of attentional resources and impaired processing compared to LSAs (i.e., diminished P3b, larger and later onset of CNV amplitude) and impaired processing efficiency (i.e., slowed categorization of cues) during interoceptive threat (i.e., later onset of P3b). As predicted by an integration of attentional control theory and cognitive models of social anxiety, this suggests that socially anxious individuals recruit more attentional resources to categorize stimuli and prepare to make an upcoming response, and that this is especially the case during self-focused attention. The interference of attentional biases with processing efficiency and ensuing impairment in social behaviors may serve to perpetuate anxious symptomatology. Thus, attentional biases and other cognitive processes which impair executive control over attention may be important to target in treatment

There are several limitations to the current study. An undergraduate convenience sample was used rather than a clinical sample. However, current models suggest that social anxiety and its pathological variants are on a continuum rather than being distinct categories (Crome, Baillie, Slade, & Ruscio, 2010; Rapee & Heimberg, 1997). Furthermore, non-clinical samples are typically used in studies investigating attentional control theory, which predicts that even sub-clinical levels of anxiety can interfere with information-processing. Nevertheless, additional research using a clinical sample is needed to verify that the results of the current study generalize to the clinical population. Another limitation is that the HSA group differed from the LSA group across a number of variables. However, the differences observed are common for socially anxious samples, and it is likely that attempts to control for these covariates would reduce the generalizability of the results (see Miller & Chapman, 2001). The HEOG approach to eye-tracking represents a third limitation. This technique is of lower spatial resolution compared to video-based eye-tracking. Future studies are needed in order to test the predictions of ACT in a clinical sample using alternative methodology.

In summary, the current study addresses questions related to attentional control theory, cognitive models of social anxiety, and the integration of their predictions. The results generally support these theories and the relevance of attentional control theory to models of social anxiety disorder. The current study suggested that self-focused attention may play a role in the impaired attentional control predicted by both theoretical perspectives. It is possible that other processes associated with social anxiety, such as anticipatory processing, play a role in impairing attentional control. Future research may expand upon the current findings by examining the role of this and other cognitive processes in the context of attentional control theory.

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APPPENDICES

Oklahoma State University Institutional Review Board

Date:	Wednesday, July 20, 2011
IRB Application No	AS1169
Proposal Title:	Attention and Distraction
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved Protocol Expires: 7/19/2012

Principal Investigator(s):

Matt R. Judah
312 N. Murray
Stillwater, OK 74078

DeMond Grant
205 N. Murray
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

Demographic Information

DATE (mm-dd-yy):

☐☐-☐☐-☐☐

1. What is your sex? ☐ 1= Male, 2=Female

2. Age: ☐☐ (years)

3. Year in School: ☐☐

4. 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	7 =	Mixed (White/Asian)
2 =	African-American	8 =	Mixed (other) - Specify: ________
3 =	Asian		
4 =	Latino	9 =	Other – Specify: ________
5 =	Mixed (White/African-American)		
6 =	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 $\geq$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 $\geq$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? ____________________

SIAS

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

	Not at all	Slightly	Moderately	Very	Extremely
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

CES-D

Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way in the past week.

DURING THE PAST WEEK

Rarely or none of the time (less than 1 day)	Some or a little of the time (1 – 2 days)	Occasionally or a moderate amount of time (3 – 4 days)	Most or all of the time (5 – 7 days)
0	**1**	**2**	**3**

_______ 1. I was bothered by things that usually don't bother me.

_______ 2. I did not feel like eating; my appetite was poor.

_______ 3. I felt that I could not shake off the blues even with help from my family or friends.

_______ 4. I felt I was just as good as other people.

_______ 5. I had trouble keeping my mind on what I was doing.

_______ 6. I felt depressed.

_______ 7. I felt that everything I did was an effort.

_______ 8. I felt hopeful about the future.

_______ 9. I thought my life had been a failure.

_______ 10. I felt fearful.

_______ 11. My sleep was restless.

_______ 12. I was happy.

_______ 13. I talked less than usual.

_______ 14. I felt lonely.

_______ 15. People were unfriendly.

DURING THE PAST WEEK

Rarely or none of the time (less than 1 day)	Some or a little of the time (1 – 2 days)	Occasionally or a moderate amount of time (3 – 4 days)	Most or all of the time (5 – 7 days)
0	**1**	**2**	**3**

______ 16. I enjoyed life.

______ 17. I had crying spells.

______ 18. I felt sad.

______ 19. I felt that people dislike me.

______ 20. I could not get “going.”

CFQ

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened to you in the last six months. Please circle the appropriate number.

0 = Never
1 = Very rarely
2 = Occasionally
3 = Quite often
4 = Very often

1. Do you read something and find you haven't been thinking about it and must read it again?	0	1	2	3	4
2. Do you find you forgot why you went from one part of the house to the other?	0	1	2	3	4
3. Do you fail to notice signposts on the road?	0	1	2	3	4
4. Do you find you confuse right and left when giving directions?	0	1	2	3	4
5. Do you bump into people?	0	1	2	3	4
6. Do you find you forget whether you've turned off a light or a fire or locked the door?	0	1	2	3	4
7. Do you fail to listen to people's names when you are meeting them?	0	1	2	3	4
8. Do you say something and realize afterwards that it might be taken as insulting?	0	1	2	3	4
9. Do you fail to hear people speaking to you when you are doing something else?	0	1	2	3	4
10. Do you lose your temper and regret it?	0	1	2	3	4
11. Do you leave important letter unanswered for days?	0	1	2	3	4
12. Do you find you forget which way to turn on a road that you know well but rarely use?	0	1	2	3	4

0 = Never
1 = Very rarely

2 = Occasionally
3 = Quite often
4 = Very often

13. Do you fail to see what you want in a supermarket (although it's there)?	0	1	2	3	4
14. Do you find yourself suddenly wondering whether you've used a word correctly?	0	1	2	3	4
15. Do you have trouble making up your mind?	0	1	2	3	4
16. Do you find you forget appointments?	0	1	2	3	4
17. Do you forget where you put something like a newspaper or a book?	0	1	2	3	4
18. Do you find that you accidentally throw away the thing you want and keep what you meant to throw away? (as in the example of throwing away the matchbox and putting the used match in your pocket)	0	1	2	3	4
19. Do you daydream when you out to be listening to something?	0	1	2	3	4
20. Do you find you forget people's names?	0	1	2	3	4
21. Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	0	1	2	3	4
22. Do you find you can't quite remember something although it's on the tip of your tongue?	0	1	2	3	4
23. Do you find you forget what you came to the shops to buy?	0	1	2	3	4
24. Do you drop things?	0	1	2	3	4
25. Do you find that you can't think of anything to say?	0	1	2	3	4

STAI

A number of statements which people have used to describe themselves are given below. Read each statement and use the following scale to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1	2	3	4
Not At All	Somewhat	Moderately So	Very Much So

_____ 1. I feel calm.

_____ 2. I feel secure.

_____ 3. I am tense.

_____ 4. I feel strained.

_____ 5. I feel at ease.

_____ 6. I feel upset.

_____ 7. I am presently worrying over possible misfortunes.

_____ 8. I feel satisfied.

_____ 9. I feel frightened.

_____ 10. I feel comfortable.

_____ 11. I feel self-confident.

_____ 12. I feel nervous.

_____ 13. I am jittery.

_____ 14. I feel indecisive.

_____ 15. I am relaxed.

_____ 16. I feel content.

_____ 17. I am worried.

_____ 18. I feel confused.

_____ 19. I feel steady.

_____ 20. I feel pleasant.

Read each statement below and indicate how you generally feel. Do not spend too much time on any one item but give the answer which seems to be best describe how you generally feel.

1	2	3	4
Almost Never	Sometimes	Often	Almost Always

______ 21. I feel pleasant.

______ 22. I feel nervous and restless.

______ 23. I feel satisfied with myself.

______ 24. I wish I could be as happy as others seem to be.

______ 25. I feel like a failure.

______ 26. I feel rested.

______ 27. I am “calm, cool, and collected.”

______ 28. I feel that difficulties are piling up so that I cannot overcome them.

______ 29. I worry too much over something that really doesn’t matter.

______ 30. I am happy.

______ 31. I have disturbing thoughts.

______ 32. I lack self-confidence.

______ 33. I feel secure.

______ 34. I make decisions easily.

______ 35. I feel inadequate.

______ 36. I am content.

______ 37. Some unimportant thought runs through my mind and bothers me.

______ 38. I take disappointments so keenly that I can’t put them out of my mind.

______ 39. I am a steady person.

______ 40. I get in a state of tension or turmoil as I think over my recent concerns and interests.

ATTC

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

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

VITA

Matthew Ryan Judah

Candidate for the Degree of

Master of Science

Thesis: THE NEURAL CORRELATES OF IMPAIRED ATTENTIONAL CONTROL IN SOCIAL ANXIETY: AN ERP STUDY

Major Field: Psychology

Biographical:

Education:

Completed the requirements for the Bachelor of Arts in psychology at Ozark Christian College, Joplin, MO in 2007.

Experience:

Assisted with research as a post-baccalaureate research assistant at the University of Kansas Cognitive-Clinical Lab and Attention and Emotion Lab

Assisted with research as a graduate research assistant at the Oklahoma State University Laboratory of Emotion and Psychophysiology.

Professional Memberships:

American Psychological Association
Association for Behavioral and Cognitive Therapies
Southwestern Psychological Association

Publications:

Judah, M. R., Grant, D. M., Lechner, W. V., & Mills, A. C. (Accepted with minor revisions). Working memory load moderates late attentional bias in social anxiety. *Cognition & Emotion*.

Judah, M. R., Grant, D. M., Mills, A. C., Lechner, W. V., Slish, M. L., Davidson, C. L., & Wingate, L. R. (Accepted with minor revisions). The prospective role of depression, anxiety, and worry in stress generation. *Journal of Social & Clinical Psychology*.

Davidson, C. L., Wingate, L. R., Grant, D. M., Judah, M. R., & Mills, A. C. (2011). Interpersonal suicide risk and ideation: The influence of depression and social anxiety. *Journal of Social & Clinical Psychology, 30*, 842-855.

Name: Matt R. Judah Date of Degree: July 2012

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE NEURAL CORRELATES OF IMPAIRED ATTENTIONAL CONTROL IN SOCIAL ANXIETY: AN ERP STUDY

Pages in Study: 94 Candidate for the Degree of Master of Science

Major Field: Clinical Psychology

Scope and Method of Study:
Cognitive models of social anxiety disorder posit that cognitive processes associated with social anxiety, such as self-focused attention, influence behaviors in feared social environments. However, these models are relatively nonspecific about the effects and basic mechanisms of this process. The current study drew from attentional control theory in order to provide specific predictions, namely, that anxiety interferes with processing efficiency, particularly in the executive control processes of inhibition and shifting. The current study tested whether socially anxious individuals demonstrated impaired processing efficiency at the neural and behavioral level, and whether this was exacerbated by a manipulation of self-focused attention. Thirty-two (16 socially anxious, 16 non-anxious controls) subjects completed a mixed-antisaccade task with a circle which appeared around the instructional cue on 20% of trials. Participants were told that this circle indicated elevated heart rate. Eye-movements were measured using horizontal electrooculography, and event-related brain potentials were derived from EEG data collected during the task.

Findings and Conclusions:
Socially anxious individuals reported that the heart rate feedback made them more self-conscious and interfered more with their performance on the task compared to controls. The socially anxious group also demonstrated impaired processing efficiency as indicated by delayed onset of correct saccades compared to controls, but made fewer errors. Additionally, socially anxious individuals had lower P3b amplitude compared to controls, suggesting greater effort in discriminating cues, and later P3b latency for trials on which heart rate feedback was present, suggesting delayed cue categorization. Furthermore, socially anxious individuals had greater CNV negativity compared to controls, suggesting greater recruitment of attentional resources for response preparation, and later onset of this component, suggesting delayed response preparation. These results were as hypothesized and are generally consistent with attentional control theory. The current study supports the applicability of this model for cognitive theories of social anxiety and expands these theories by providing evidence of impaired neural and behavioral functioning in social anxiety, especially as a result of self-focused attention.

ADVISER'S APPROVAL: Dr. DeMond M. Grant