THE FEAR SURVEY SCHEDULE AS A SENSITIVE MEASURE OF STRESS: EVIDENCE FROM ERPS

BY

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Abstract

Working within the framework of the dual-anxiety model (Barlow, 1988; Dien, 1999; Gray, 1982; Gray & McNaughton, 2000; Heller, Nitschke, & Miller, 1988; Ohman & Mineka, 2001), it has been argued via electroencephalographic (EEG) recordings that different types of anxiety can be differentiated not only behaviorally and cognitively but in laterality as well (Heller, Nitschke, Etienne, & Miller, 1997). Additionally, one event-related potential (ERP) investigation found a left-lateralized N2 component associated with anxious apprehension (worry) and a right-lateralized P1r component associated with anxious arousal (fear/panic) (Dien, 1999). This study attempts to provide further support for the left-lateralization of anxious apprehension and the right-lateralization of stress (the label used for anxious arousal here). High-density ERPs were recorded from 58 participants who completed the STAI and FSS as measures of trait anxiety and stress, respectively. They also performed a spatial cueing task where happy and angry face cues were presented laterally followed by validly or invalidly cued shape targets. A temporo-spatial PCA revealed a right-lateralized posterior component (P296) that was greatest in amplitude for individuals whom scored high on the FSS, *p*=.0007. This finding further supports the idea that stress (anxious arousal) can be right lateralized. Additionally, it is suggested that either the FSS can be a more sensitive measure for this type of anxiety, or, consistent with the dual anxiety model, it measures effects different from those measured by the STAI.

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1.1 Introduction -

In a recent survey replication, anxiety disorders, as defined by the DSM-IV, were found to have the highest lifetime prevalence (28.8%) and one of the earliest onset ages (11 years) out of all mental illnesses surveyed (Kessler et al., 2005). Ten years prior to this survey, the same could have been said for depressive disorders (Kessler et al., 1994). As this indicates, anxiety is affecting a larger proportion of the population than before and begins early in life. With prevalence of clinical anxiety so high, it is probable that sub-clinical levels of anxiety affect an even larger portion of the population. Despite this, research on anxiety has not converged on a single, coherent model of anxiety and its counterparts. This is partially due to conflicting findings in the study of the effects of anxiety on attention, as well as the lack of consensus on the definition of anxiety and how it does or does not differentiate from stress/fear and panic. Resolving these issues would aid in the diagnosis and treatment of anxiety and stress disorders as well as contribute to the well being of the general population as a whole.

1.2 Effects of Anxiety and Stress on Attention -

One line of research on the effects of anxiety on attention began with an emotional version of the Stroop task. It was found that when words are negatively charged (e.g., MURDER) individuals display a delay in response time to naming the color of the ink in which that word is written, and this delay is magnified in individuals who are experiencing high levels of anxiety (Mathews & MacLeod, 1985; Ray, 1979). It was reasoned from these findings that threatening words command more processing resources in anxious individuals; however, the ability of threat stimuli to capture the attention of anxious individuals is measured indirectly in the emotional Stroop task (MacLeod, Mathews, & Tata, 1986). Another possible explanation for the effects of the emotional Stroop task is that the viewing of threatening stimuli leads to freezing behavior in anxious individuals (Cloitre, Heimberg, Holt, & Liebowitz, 1992). In this interpretation, the delay in reaction times following a threat cue would not be due to the threat cue taking more attentional processing, but rather from a brief inability to respond. A paradigm with a more direct measure of attentional processing was needed to further investigate the effects of anxiety on attention.

Following the observations from the emotional Stroop task, MacLeod, Matthews, and Tata (1986) further examined the effects of anxiety on attention through the development of the Dot Probe Detection Task. In this paradigm, two cue words would appear on a vertical axis. In critical trials, one of the cue words was emotionally threatening, and the other was emotionally neutral. For some trials, the offset of the cue words would be followed by a dot probe in the same location as one of the words. Participants' task was to respond to the probe as quickly as possible. The detection latency of the dot probe is considered a direct measure of visual attention, and thus a more direct measure of the allocation of attention to the cue words (Hoffman, Nelson, & Houck, 1983). It was found that when the probe appeared in the same location as the emotionally threatening word, high anxious participants were quicker to respond to that probe than when it appeared in the same location as the neutral word. It was concluded that anxious individuals shift their attention toward threatening visual stimuli. Other researchers would disagree with this conclusion (Fox, 2002; Fox, Russo, Bowles, & Dutton, 2001; Georgiou et al., 2005), however, claiming that in high-anxiety individuals the difference is reaction times is not due to speeded engaging of attention to threat cues but rather delayed disengagement of attention from threat cues, making responses to neutral cues slower when a threat cue is present. This perspective will be discussed in more detail.

Similar findings to those in the probe detection task have been found with pictorial stimuli as well (Bradley, Mogg, & Millar, 2000). Participants were found to differentially attend to threatening, neutral and happy faces according to their levels of anxiety. Participants were divided into three groups: high, medium, and low anxiety. They then completed a version of the dot probe detection task in which two faces appeared side-by-side on a monitor followed by a dot probe that appeared under one of the two faces. Upon analyzing the reaction times of participants to detecting the probe, it was found the high and medium anxiety participants responded more quickly to a probe that appeared under a threatening face as opposed to a neutral or happy face. The conclusion was that anxiety must result in a “hyper-vigilance” toward threat stimuli, and thus, high-anxiety individuals are able to detect threat stimuli more quickly than low-anxiety individuals. Indeed, a recent meta-analysis of 172 studies examining the effects of anxiety on attention came to similar conclusions (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van, 2007). A significant threat-related bias was found in anxious participants but not in non-anxious participants.

More recent studies by Fox and colleagues (2001; 2002) provide an alternate explanation for the attentional effects of anxiety reported above. To further explore the effects of anxiety on attention they utilized a version of the spatial cuing task (Posner & Petersen, 1990) in which cues appeared one at a time on either side of a fixation mark, indicating the location of the succeeding target most of the time. A valid trial occurred when the target appeared on the same side of the fixation as the cue, and an invalid trial occurred when the target appeared on the opposite side of the fixation as the cue. Overall, people have been found to have delayed responses during invalid trials and to facilitated responses during valid trials.

The delay in responses to invalidly cued targets can be explained by Posner and Petersen's (1990) model of the spatial attention system. According to this model, spatial attention involves three cognitive functions: disengaging from the current position, shifting to a new location, and engaging the new location. The delay in response time during invalid trials is due to the time it takes to disengage attention from the invalid location and shift it to the location of the target. Fox and colleagues (2001) argued that the results of the dot probe task could be due to difficulty disengaging from threat locations rather than attentional engagement to threat locations.

Fox and colleagues (2001; 2002) combined the spatial cueing task (Posner & Petersen, 1990) with the probe detection task (MacLeod, Mathews, & Tata, 1986) to better understand the effects of anxiety and stress on attention. In these experiments, the cues in the spatial cuing task were emotional stimuli. Which side of the fixation mark a cue appeared on would indicate where the target, a dot, would appear most of the time; however, occasionally the target would not appear on the same side of the probe. Thus, the faces could validly or invalidly cue the target. Participants were to indicate when they saw the target with a button press.

Using the model of attention discussed (Posner & Petersen, 1990), if high anxiety individuals are experiencing delays in disengaging attention from threat stimuli, or attentional "gluing", then the time it takes to disengage attention and shift it to the invalidly cued target should be even longer for this group following an angry face than non-anxious individuals. If the effects of anxiety on attention were speeded engagement of attention to threat stimuli, as proposed by MacLeod and colleagues (1986) and others (Bradley, Mogg, & Millar, 2000; Mercado, Carretie, Tapia, & Gomez-Jarabo, 2006), quicker responses to validly cued targets following angry face cues should have been recorded instead.

The first investigation on this matter by Fox and colleagues (2001) involved a 5-part study. The first study used emotional words as the cues in the spatial cuing paradigm, and state anxiety was induced via the viewing of emotional images prior to the experimental task. No effects for level of anxiety were found to interact with threatening words; however, a main effect for cue valence was found in invalid trials, such that negative stimuli had slower RTs than neutral and positive stimuli overall. The second study used a more biologically salient cue, normal and jumbled schematic emotional faces and no mood induction. Two different cue exposure durations were used, 100 and 250 ms. All participants experienced both conditions. It was found that high anxiety individuals were slower to respond to invalidly cued targets following a normal angry face only in the long cue exposure (250 ms) condition. All participants were slower to respond to targets following angry-invalid cues in the 100 ms cue presentation condition. This was explained by threat cues having attentional hold properties at short displays, but when additional processing time is available, the effect only carries over to high anxious participants.

To ensure that the effects from the second study were not spurious due to the large number of factors, a third study was conducted with only the 250 ms cue exposure condition and only normal faces. A 3-way interaction between state anxiety, cue validity and cue valence was found, such that high anxiety individuals were slower to respond to targets invalidly cued by angry faces. High anxious participants were also faster to detect a target validly cued by happy faces. It is possible that the validity effects found in the first three studies were due to response preparation from the informative cue, and thus the angry face could be more disrupting to the prepared motor responses of high anxious participants than to their attentional disengagement. To control for this, a one-button-response was used in the fourth study, such that participants only had to respond to the target, not the location of the target. Additionally, to ensure that there were no attention shift effects during valid trials, the targets were presented in the same location as the cues rather than in the lower part of the same box. “Catch” trials were included in which no target appeared. Actual photographs of faces were used as cues for this study. It was found that the trial validity by face valence interaction was marginally significant (*p* = .054) in high anxiety individuals. To more directly address attentional disengagement processes, a fifth study used central presentations of neutral, positive, and threat words that remained present during the target discrimination task. It was found that high anxious individuals were slower to respond to targets during the presentation of threat words than neutral or positive words.

Overall, Fox and colleagues first investigations found that individuals who self-reported high levels of anxiety were more likely to be slower to respond to invalidly cued targets following an angry face than low-anxiety individuals (Fox, Russo, Bowles, & Dutton, 2001). Thus, the results supported anxiety having an effect of attentional "gluing" to threat stimuli, suggesting that it is a delay in disengagement of attention that is responsible for the differences in reaction times.

Additionally, Fox and colleagues (2002) examined inhibition of return (IOR) effects with high anxious individuals in a second investigation. The effect of IOR is the tendency for returning attention to a previously attended location to be inhibited (Abrams & Dobkin, 1994; Posner & Raichle, 1995). IOR has only been found in paradigms that utilize exogenous cues (i.e., peripheral cue stimuli) but not in paradigms that utilize endogenous cues (i.e., an arrow at fixation) (Posner & Cohen, 1984; Rafal, Calabresi, Brennan, & Sciolto, 1989). IOR would certainly be a concern in a spatial cuing task that used peripheral cues, such as the faces in the paradigm above. If the SOA is long enough, participants may move their attention away from the cued location naturally, thus during validly cued trials, they may experience an IOR to the previously cued location; however, IOR effects are thought to occur following SOAs of 600 ms or longer (Posner & Cohen, 1984). Fox and colleagues (2002) postulated that if high anxious individuals are experiencing delayed disengagement of attention from threat stimuli that they should also experience reduced IOR effects following threat cues as it will take longer for their attention to shift away from the cued location. They investigated this theory with three more studies.

The first study was conducted in an attempt to replicate the findings from their 2001 study (Fox, Russo, Bowles, & Dutton, 2001). Again, schematic faces were used in a spatial-cuing paradigm; however, target categorization was used as the task to show that the predicted delayed reaction times following targets invalidly cued by angry faces in high anxiety individuals were not due to the prediction of the response, but rather, attentional effects. Thus, where the cue appeared did not provide information as to what response would need to be made. The effect of anxiety on reaction times to invalidly cued targets following angry face cues was only a statistical trend (*p* = .06). When data from high anxiety individuals was analyzed alone, slower RTs were found for targets invalidly cued by both angry and happy faces. Thus the original findings by Fox and colleagues (2001) that high-anxiety individuals experience a delay in disengaging attention from threat stimuli in a spatial-cuing paradigm without IOR still need to be bolstered by replication.

Experiment two looked at IOR effects, thus target localization rather than discrimination and an SOA of 960 ms was used. Valid and invalid trials were equal in frequency of presentation. It was found that overall, IOR effects were reduced following angry face presentations; however, no difference was found between high and low anxiety individuals in reaction times. A mood induction was used in the third study to elevate state anxiety levels and hopefully increase the decreased IOR effects following threat cues in high anxiety individuals. For this study, only angry and neutral faces were used as cues, as well as a jumbled angry face to examine if the effects are due to low-level visual features of the faces. It was found that high anxious individuals had reduced IOR effects to both angry and angry-jumbled faces. The effect for jumbled-angry faces was not predicted; however it may be interpreted as high-anxious individuals trying to resolve the ambiguity of a threat, as the jumbled-angry faces were rated as more threatening than the neutral or neutral-jumbled faces.

At least one study has tried to confirm Fox and colleagues' (2001; 2002) findings using ERP methodologies (Bar-Haim, Lamy, & Glickman, 2005). In this study, photograph cues of angry, fearful, sad, happy, and neutral faces were centrally presented. Face cues remained present for the presentation of the target, which could occur to either the side, top, or bottom of the face cue. Participants' task was to discriminate the shape of the target with a button press. A main effect for group (high anxiety/low anxiety – as determined by scores on the Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger, 1983)) was found, such that high anxiety individuals were slower to respond to targets overall. The only group by cue emotion interaction found was for the P2 component. The P2 was found to be larger in high anxious individuals only for the presentation of angry face cues. In visually inspecting the grand average ERP waveforms reported in this study, however, it appears that the baselines across groups are not equal. This may have resulted in the high-anxiety group appearing to have an increase in P2 amplitude, when in fact, their waveform simply started out at a more negative amplitude overall. One potential cause of such differences in baselines may be the presence of a contingent negative variation (CNV) in the high-anxiety group. A CNV typically occurs prior to an expected stimulus (Tecce, 1972), thus in this paradigm a CNV may occur after the face cue appears indicating that a target will be appearing soon. Thus, it is possible that in this dataset the increase seen in the P2 for the high-anxiety group is actually due to the high-anxiety group being more expectant of the target. Other main effects for group were found in the latencies of ERP components. The N1, P1, and P2 were all found to have faster latencies in high anxiety individuals than low anxiety individuals. As these ERP components are thought to index the allocation of visual attention to a stimulus, it seems that this study has provided support for high anxiety individuals having early engagement of attention overall than low anxiety individuals. As to date, ERP evidence that contributes to the effects of anxiety on the disengaging of attention still needs to be provided.

Rather than the debate on the effects of anxiety on attention being between attentional engagement or disengagement effects, it is possible that the dual-anxiety models may account for both of these findings. The evidence for anxiety to lead to a speeded detection of threat cues has been well established (MacLeod, Mathews, & Tata, 1986). Fox and colleagues' (2001; 2002) challenge of the early-detection of threats in high anxious has yet to garner enough support to fully discredit this theory, though their conflicting results do need explained in light of the early-detection theory. The current study is designed to look at the possibility that both attentional effects can exist but are caused by different emotional states. For the purposes of this paper, it could be argued that it is not high anxiety but high stress that results in a speeded attentional engagement to threat stimuli, and high anxiety that results in the delayed attentional disengagement from threat stimuli. In order to be sure, however, a study needs to be run that assesses levels of stress and anxiety separately as well as utilizes a paradigm that can look at both properties of attention. First, however, what a dual-anxiety model encompasses must be discussed.

1.2 Dual-Anxiety models-

It has been recognized that when referring to anxiety, two fundamental aspects need to be considered. According to the American Psychiatric Dictionary (1994), anxiety is: "Apprehension, tension, or uneasiness from anticipation of danger, the source of which is largely unknown or unrecognized. Primarily of intra-psychic origin, in distinction to fear, which is the emotional response to a consciously recognized and usually external threat or danger." The distinction between anxiety and fear made here is also reflected in the DSM-IV-TR definitions of specific anxiety disorders, with obsessive-compulsive disorder (OCD) and generalized anxiety disorder (GAD) being more characteristic of anxiety as described above with symptoms of “recurrent obsessions (p. 456)” and “excessive worry or apprehensive expectation (p. 472)” respectively, and panic attacks and phobias being more characteristic of fear as described above with symptoms of “acute fear with palpitations, sweating, trebling, shaking…(p. 430)” and “persistent fear of clearly discernable object or situation (p. 443)” respectively. For the purposes of this paper, “anxiety” will be used to refer to the emotional construct that includes symptoms of apprehension and worry as mentioned above, and will be characterized by the behavior of attempting to evaluate and recognize threats and dangers. It is assumed that anxiety results in the gluing of attention to threat stimuli in an attempt to fully analyze the threat. On the other hand, “stress” will be used to refer to the emotional construct that includes symptoms of hyper-arousal and will include fear responses. Behaviorally, fear will be considered to result in escape from threat and danger. It is assumed that stress results in hyper-vigilance for threat stimuli, and thus, speeded engagement of attention to threats.

Clearly establishing the operational definitions for the terms of the emotional constructs discussed here is important as much of the confusion over the effects of anxiety and stress is due to inconsistent uses of the terms "stress", "fear", "panic", and "anxiety" in the literature (Gray, 1991). In the examination of these properties, some have treated them as constructs of the same emotional state (Gray, 1982; Heller, Nitschke, Etienne, & Miller, 1997), and others have treated them as entirely different emotional constructs (Dien, 1999; Lang, Bradley, & Cuthbert, 1998; Lang, Davis, & Ohman, 2000; Ohman & Mineka, 2001). In order to determine the dissociation between anxiety and stress, researchers have looked at the regional brain functionality of the constructs (Gray, 1982; Gray & McNaughton, 2000; Lang, Bradley, & Cuthbert, 1998; Lang, Davis, & Ohman, 2000), the laterality of the constructs (Dien, 1999; Engels et al., 2007; Heller, Nitschke, Etienne, & Miller, 1997; Heller, Nitschke, & Miller, 1988; Nitschke, Heller, Palmieri, & Miller, 1999), and the cognitive effects of the constructs (Bar-Haim, Lamy, & Glickman, 2005; Fox, 2002; Fox, Russo, Bowles, & Dutton, 2001; MacLeod, Mathews, & Tata, 1986). Unfortunately, in these pursuits, each group of researchers has used their own operational definitions and labels to describe and examine the worry and the arousal aspects of anxious emotionality.

Some of the most prominent work on parsing apart different aspects of anxiety was done by Gray (1982) and Gray and McNaughton (2000) through animal research and biological models. According to their models, anxiety and fear are subcomponents of the same emotional construct, as they both are a result of over-activity of the Behavioral Inhibition System (BIS), while panic is considered distinct from anxiety as it is a result of over-activity of the fight/flight system. According to the original model (Gray, 1982), the BIS was activated by conditioned punishment and non-reward stimuli (signals of punishment, signals of non-reward, novel stimuli, and innate fear stimuli) and outputted behavioral inhibition, increment in arousal and increased attention (p. 12). All three of these outputs were considered to be controlled by the septo-hippocampal system and ultimately resulted in passive avoidance. This model has been updated in the more recent version of the model, however (Gray &

McNaughton, 2000). In this model, the BIS is responsive to innate and acquired signals of punishment, innate and acquired signals of frustration, and initially threatening novel stimuli. Key to this model, all of these stimuli types are thought to be aversive and create situations where the resolution of an approach-avoidance conflict is necessary (p.86). In this model, the septo-hippocampal system does not output the increase in arousal associated with activation of the BIS, but rather, the amygdala is cited for this function (p. 159). Instead, the septo-hippocampal system serves as a conflict detector, hence functions as a comparator where its actions are carried out under environmental uncertainty and are goal-oriented. Still, the main output of the septo-hippocampal system is the inhibition of behavior, both of behavioral approach and the fight-flight system. Conversely, the fight/flight system is activated by unconditioned punishment, unconditioned frustrative non-reward by defense aggression, and/or escape behavior and is thought to be elicited by stimulation of the medial hypothalamus and the central periaqueductal grey (p. 3). While differences between anxiety/fear and panic are made clear by the separateness of the systems they are involved in, the differences between anxiety and fear require a more intricate examination to distinguish.

Gray's model (2000) focuses on two major structures within the limbic system, the amygdala and the septo-hippocampal system. The amygdala is responsible for the increase in arousal and autonomic responses, and is thus thought to be more responsible for fear (p. 8). It is through the amygdala's interactions with the septo-hippocampal system (Gray, 2000 p. 2) that the symptoms of anxiety are produced. According to Gray (1991), the ascending noradrenergic projection to the septo-hippocampal system is found to control labeling when a stimulus was “important”, requiring vigilant checking of the environment, and has thus been labeled the comparator network (Gray & McNaughton, 2000). The theta activity of the hippocampus, an electrophysiological signature of the coordinated firing of neurons in this area, is found to be affected by anxiolytic drugs only, and thus this seems to be a critical area for the origination of anxiety. It is postulated that this circuit is likely responsible for was has been termed “anticipatory frustration” (Amsel, 1962). This circuit has also been found to be involved in the checking behaviors of obsessive-compulsive disorder (OCD) patients (Gray, 1982). It is also likely that the connections of the entorhinal area and the hippocampus to the language areas of the temporal lobe play a role in the verbal rehearsal of the obsessions of OCD patients (chap. 14, p. 442) (see (Rachman & de Silva, 1978).

Essentially, Gray (1982; 2000) establishes two neural circuits within the rat brain that seem responsible for the two major characteristics of anxiety. According to his model, the dorsal noradrenergic projection to the hippocampus regulates activity of the BIS. The projections from here to the amygdala elicit symptoms of fear, increased heart rate, sweaty palms, etc. Additionally, a network within the septo-hippocampal system detects mismatches in predicted outcomes and threats. To solve these mismatches, values of importance are given to the situation. Over-activity of this system results in the apprehension seen in anticipatory frustration (Gray, 2000, p. 20). Despite these distinctions, worry (anticipatory frustration) and fear are considered to be subsets of the same emotional construct. Thus, the term "anxiety" encompasses the activation of both of these neural circuits, as they both involve different aspects of the BIS. Fear is the part of the BIS that includes increased arousal, while anxiety is the part of the BIS that interrupts ongoing behavior to allow the increase in attention for information to be gathered to solve the potential threat.

Another prominent anxiety model is postulated by Barlow (1988; 1996). This model recognizes anxiety and fear as well; however, it treats them as fundamentally different emotions phenomenologically, behaviorally, psychometrically, and neurobiologically (Barlow, Chorpita, & Turovsky, 1996; Barlow, 1988; Bouton, Mineka, & Barlow, 2001). According to this model, anxiety is best termed anxious apprehension as it stems from unpredictability and uncontrollability and is characterized by a preoccupation with negative events in the future (Barlow, 1991, p. 60; 2000) (Fig. 1). In this sense, anxiety can be considered to be adaptive up to a point, as is consistent with the Yerkes-Dodson Law (1908) (Yerkes & Dodson, 1908) (Fig. 2). Fear, on the other hand, is considered the classic fight-or-flight response, termed as such from Cannon's (1927) "emergency response" or "alarm reaction" (Cannon, 1927). Fear is considered a disorder of stress in this model. Stress disorders differ from anxiety disorders in that individuals deal with the discomfort by taking immediate action to alleviate the problem (this too can be adaptive as the most immediate method of relieving the discomfort may be hard work, maintaining attention, and/or having confidence). Thus, according to this model, fear/panic is differentiated from anxious apprehension:

"…there are several other reasons for considering that panic, as a clinical manifestation of fear, is…distinct from anxiety. First…panic attacks are descriptively and functionally unique events when compared to anxiety. Panic attacks present differently from anxious apprehension and are experienced differently by clients. Second…whether a panic attack…is expected or not will influence subsequent anxiety…it is conceptually difficult to consider the alternative of developing "anxiety" focused on the future experience of "anxiety." Third…Fear is thought to be a basic action tendency of fight or flight that is a tightly organized, affective structure in memory. This contrasts with anxiety which is seen as a blend of basic emotions or…a diffuse cognitive-affective structure associated with preparation for future threat or challenge" (Barlow, 1991, p. 62-63). According to this model, fear is considered a basic emotion while anxiety is not.

Figure 1. Barlow's (1991) model of anxious apprehension.

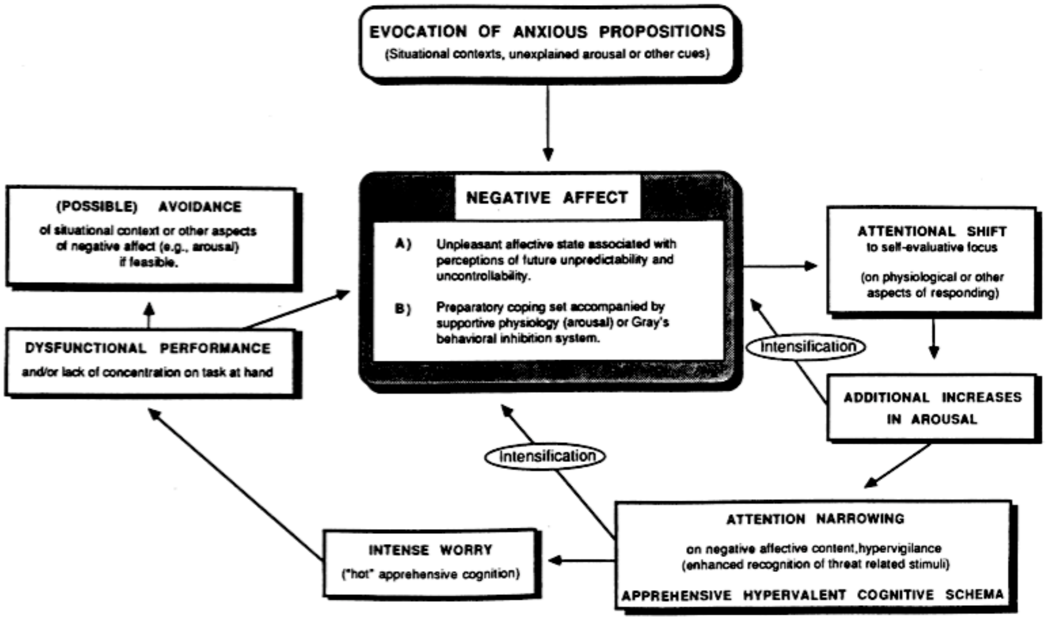
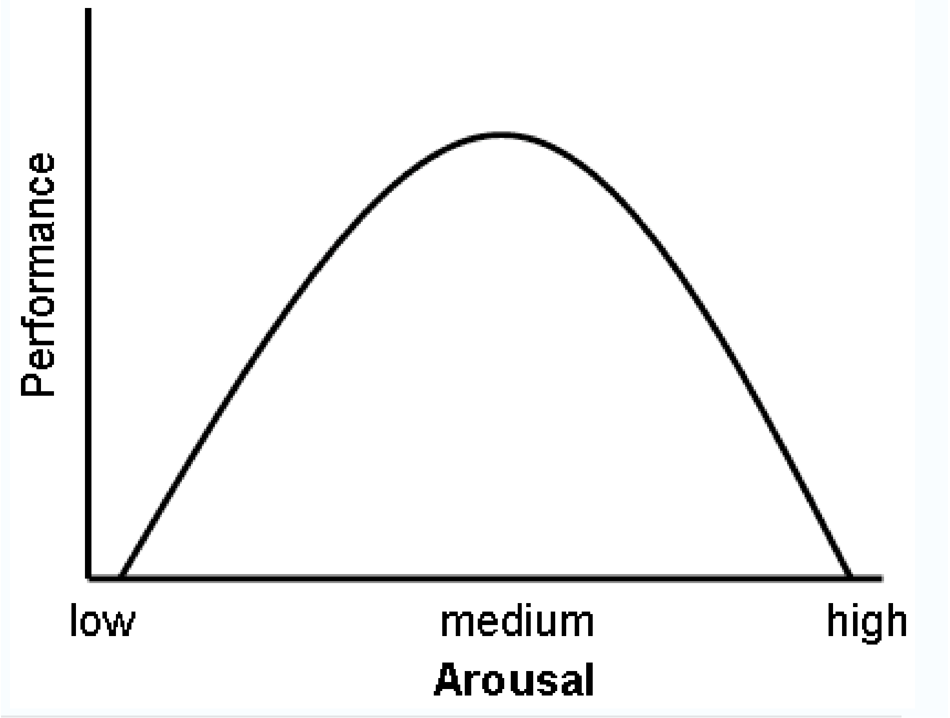
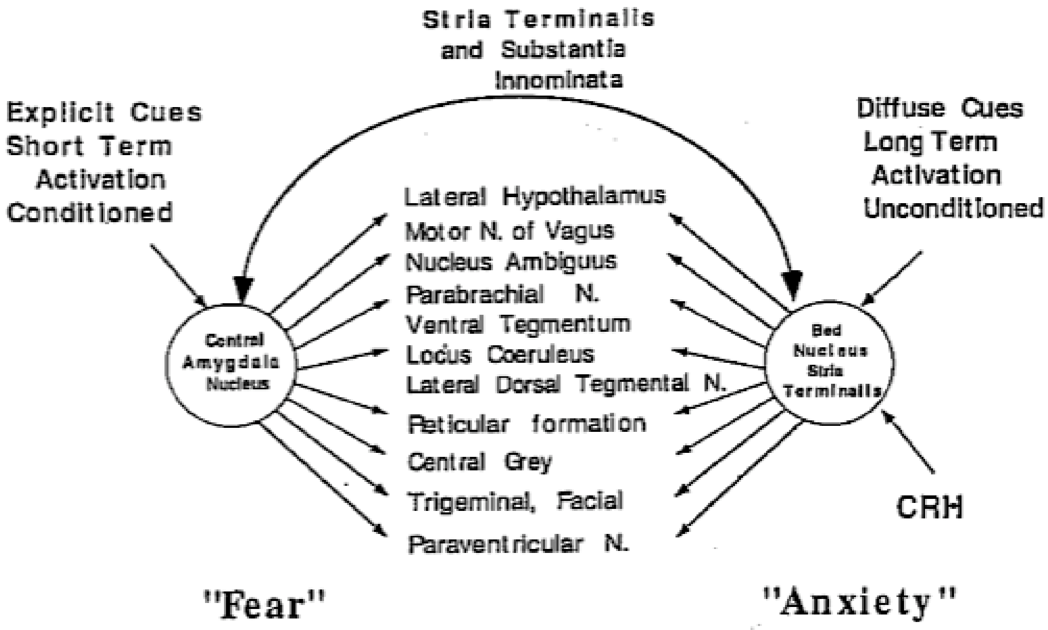


Figure 2. The Yerkes-Dodson Law (1908) performance-arousal curve.



Other theories of anxiety (Lang, Bradley, & Cuthbert, 1998; Lang, Davis, & Ohman, 2000) have been based on biological models (Lee & Davis, 1997) as well. The anxiety model proposed by Lang and colleagues (1990; 1998; 2000) is founded on the examination of the startle response, specifically the startle eye-blink. Originally, it was found that the startle-response is affectively congruent in humans, meaning that when an aversive as opposed to appetitive mood state is induced, the startle-response is accentuated (Lang, Bradley, & Cuthbert, 1990). When the startle-response was investigated in more detail in rats (Lee & Davis, 1997), it was found that lesions to the central nucleus of the amygdala eliminated cue-specific startle-responses, such as to a loud noise or a light that had been fear-conditioned. Post-lesioning of the amygdala's central nucleus, it was observed that injecting the rat with corticotropin-releasing hormone (CRH) elicited a different type of startle response that more resembled being in a prolonged state of high arousal (Hitchcock & Davis, 1991). This state was found to be controlled via the bed nucleus of the stria terminalis. It was concluded from these observations that the central nucleus of the amygdala and the bed nucleus of the stria terminalis provided neurobiological evidence for a difference between cue-explicit fear and generalized fear of context (Fig. 3).

Figure 3. Model of neurobiology of fear and anxiety.



Lang and colleagues (1998; 2000) extended the findings on rats (Hitchcock & Davis, 1991; Lee & Davis, 1997) to humans, claiming that the immediate, cue-explicit response elicited by the central nucleus of the amygdala underlies the fear startle-response in humans to explicitly threatening stimuli, and the prolonged arousal and generalized state of distress elicited by the bed nucleus of the stria terminalis underlies anxiety. As evidence of how the startle-response circuit is evolutionarily adaptive, startle blinks have been recorded in five-month old infants (Balaban, 1995).

More work has been done on the evolutionary aspects of fear (Ohman & Mineka, 2001). As rewards and punishments occur in the environment unpredictably across space and time, it is the individuals who more quickly detect relevant stimuli that are more likely to be successful. Fear is considered to be an "independent behavioral, mental, and neural system that is specifically tailored to help solve adaptive problems prompted by potentially life-threatening situations (Ohman, Lundqvist, & Esteves, 2001)". These problems are most often solved by the motivation of avoidance and escape. Fear seems to be the manifestation of the refinement of the early detection of threats over time. This has been shown in detection paradigms with fear-relevant stimuli such as spiders, snakes, and angry faces, as has been demonstrated in the anger-superiority effect in the face-in-the-crowd task, in other words participants are quicker to detect an angry face in a matrix of happy faces than a happy face in a matrix of angry faces (Hansen & Hansen, 1988; Ohman, Flykt, & Esteves, 2001). Additionally, individuals with specific phobias have been found to be more likely to detect the source of that phobia than others (Ohman, Dimberg, & Ost, 1985). In particular, it has been shown that using a "face-in-the-crowd" task with matrices of mushrooms, flowers, snakes and spiders instead of faces also results in the quicker detection of fear-relevant stimuli regardless of matrix size (Ohman, Flykt, & Esteves, 2001). This has been used to suggest a separate, pre-attentive, parallel processing route for fear-relevant stimuli, while neutral stimuli seem to be processed in a more serial fashion. Again, these findings are for fear, which is likened to stress, as differentiated from anxiety.

Working off of the proposed emotional construct of anxious apprehension by Barlow (1991), another dual-anxiety model was developed by Heller and colleagues (1997). This model includes anxious apprehension and anxious arousal (Engels et al., 2007; Heller, Nitschke, Etienne, & Miller, 1997; Nitschke, Heller, Palmieri, & Miller, 1999). Anxious apprehension is characterized by worry and verbal rumination

(Barlow, 1991) about perceived threats in the immediate or distant future (Engels et al., 2007). Some examples of persistent worrisome thoughts are: “personal and emotional threats to self, physical health, competence at work, or general world problems” (Engels et al., 2007). Anxious apprehension also includes physical symptoms such as restlessness, fatigue, and muscle tension (Nitschke, Heller, Palmieri, & Miller, 1999). Anxious arousal, on the other hand, is characterized much more physically and as a result of threats perceived in the immediate future (Engels et al., 2007). Symptoms include somatic tension and physiological hyper-arousal: rapid heartbeat, sweating, dizziness, feeling of choking, and shortness of breath (Nitschke, Heller, Palmieri, & Miller, 1999). Although clear definitions are provided in this dual-anxiety model, anxious apprehension and anxious arousal are not considered to be mutually exclusive, and both are thought to occur to varying degrees in different disorders. Anxious apprehension is considered to be more prevalent in GAD (general anxiety disorder) and OCD, while anxious arousal is considered to be more prevalent in panic attacks and high-stress situations (Nitschke, Heller, Palmieri, & Miller, 1999).

Heller and colleagues (Engels et al., 2007; Heller, Nitschke, Etienne, & Miller, 1997; Nitschke, Heller, Palmieri, & Miller, 1999) have further developed the dual-anxiety model by arguing for differential lateralization for anxious apprehension and anxious arousal. In a study using resting EEG as a measure of brain activity, where alpha activity is considered the inverse of brain activity, a group of individuals high in anxious apprehension were examined (Heller, Nitschke, Etienne, & Miller, 1997). It was found that overall, the high anxious apprehension group had more brain activity over their left frontal lobe than their right; however, when a state of anxious arousal was induced via auditory emotional narratives, more activity was recorded over the right posterior area than the left. While these results do suggest that anxious apprehension may be left lateralized and anxious arousal may be right lateralized in general, this study does not create a double-dissociation between the two. Additionally, a follow-up study found more activity over the right hemisphere for high anxious arousal individuals but found no effects for anxious apprehension (Nitschke, Heller, Palmieri, & Miller, 1999). Again, anxious apprehension is likened to "anxiety" as used in this paper, and anxious arousal is likened to "stress".

More recently, the issue of dissociating the hemispheric lateralities of anxious apprehension from anxious arousal has been revisited (Engels et al., 2007). Using fMRI and the emotional Stroop task, three groups were scanned. The first was high anxious apprehension, categorized as individuals who scored within the top 80% on the Penn State Worry Questionnaire (PSWQ) and the bottom 50% on the Mood and Anxiety Symptom Questionnaire (MASQ). The second was high anxious arousal, categorized as individuals who scored within the top 80% on the MASQ and the bottom 50% on the PSWQ. Finally, a control group, categorized as scoring around 50% on both questionnaires, was used for comparison purposes. The left inferior frontal gyrus was found to be more active to negative than neutral words in anxious apprehension, and the right inferior temporal gyrus was found to be more active to negative than neutral words in anxious arousal. These data provide convincing evidence for the separate lateralities of anxious apprehension and anxious arousal; however, the lack of effects in the parietal regions means that these findings are not supported by the original model proposed by Heller and colleagues (1997), as it specifically places anxious arousal in the right parietal cortex and does not allow this theory to speak to the effects of anxiety and stress on attention. Considering that resting EEG asymmetry was the methodology previously used to determine the locations of anxious apprehension and anxious arousal (Heller, Nitschke, Etienne, & Miller, 1997), it is likely that the fMRI results reported (Engels et al., 2007) provide more accurate locations for activity associated with anxious apprehension and anxious arousal. Thus, it is likely that the original model proposed by Heller and colleagues (1997) needs to be revised to include both the right parietal and right temporal posterior areas as likely sources for the differential cognition of anxious arousal.

One other model of anxiety has been developed for the differential lateralization of the worry and the high arousal aspects of anxiety (Dien, 1999). For this model, worry (anxious apprehension, context general fear) was measured by the STAI-Trait (STAI-T) and was termed anxiety, and high-arousal (stress, panic, cue-explicit fear) was measured by the Fear Survey Schedule (FSS) (Braun & Reynolds, 1969) and was termed fear. In this manner, anxiety and fear were considered entirely dissociable constructs, both cognitively and in brain laterality. Participants completed two tasks, one in which they needed to report if a moving number was even or odd and another in which they needed to report if the moving number was going up or down. Scores on the STAI and FSS were correlated with lateralized factors. Through a principal components analysis (PCA) it was found that a left-lateralized N1 component that localized to the left inferior-temporal gyrus was present for high STAI individuals, and a right-lateralized P1r component that localized to the right superior temporal cortex (occurring 300 ms post-stimulus) was present for the high FSS individuals. While the P!r component is consistent with the original predictions for the location of anxious arousal in Heller and colleagues' (1997; Nitschke, Heller, Palmieri, & Miller, 1999) dual anxiety model, it too does not mesh with the findings from Engel and colleagues (2007) fMRI localizations. Inspection of the dipole for the P1r reveals that it is aligned vertically and thus may originate more inferiorly in the cortex than its distributed scalp activation represents; thus it is likely that the P1r is a temporal activation as well. Again, fear is being considered the portion of the FSS not correlated with the STAI as it is measured on the residualized FSS scores, thus a clear dissociation between the neurophysiology of high trait anxious and high trait fearful individuals was obtained (Dien, 1999). Additionally, the residualized FSS could arguably be considered a better measure of fear than the STAI here because it had a stronger correlation with the P1r measure than the raw FSS score.

Interestingly, another ERP investigation (Kolassa & Miltner, 2006) found an increased P1 component over right posterior sites to correspond with high FSS scores during the gender or valence classification of emotional faces and an increased right-lateralized N170 component that corresponded with Social Phobia and Anxiety

Inventory (SPAI) scores and viewing angry faces in social phobics, but no effects were found for the STAI-T in this group.

These two ERP studies (Dien, 1999; Kolassa & Miltner, 2006) yielded results that were somewhat discrepant with each other. Although both reported right-lateralized effects correlating with the FSS, the components were quite different in nature. The so-called P1r component (Tucker, Liotti, Potts, Russell, & Posner, 1994), despite the name reported by the earlier study, actually peaks at about 300 ms whereas the effect found in the latter study peaked at about 104 ms. Furthermore, only the former study found a left-lateralized effect correlating with STAI-T. One possible reason is the difference in the stimuli (numbers in the former and faces in the latter), which are stimuli that tend to be favored by the left and right hemispheres respectively. Additionally, in the latter study, one of the tasks was to directly process the emotional content of the faces, which was done to directly influence the cognitive processes of the participants' phobias. Another possibility is the difference in the nature of the participants (college students in the former and individuals with social phobia in the later). Due to these differences, it is unclear what these differences in ERP effects signify.

Another ERP study, discussed earlier (Bar-Haim, Lamy, & Glickman, 2005) needs to be reconsidered within the framework of the dual-anxiety models as well. Participants for this study were determined to be high or low anxiety via their scores on the STAI. According to the dual-anxiety research discussed, this would suggest that these participants were being measured on levels of anxious apprehension;

however, the magnified P2 to angry faces in high anxiety individuals and the earlier N1/P1 and P2 components in high anxiety individuals seem to be more characteristic of earlier attentional processes seen in anxious arousal/fear. It is possible that the components found to interact with STAI scores were only relevant to the part of the STAI that correlates with the FSS, and thus are actually measuring aspects of anxious arousal.

1.4 Rationale for this Study

The current study is designed to further dissociate the emotional constructs of anxiety and stress using ERPs. The terms anxiety and stress will be used to describe the worry (anxiety) and high arousal (fear) aspects of trait emotionality for this study respectively. The ultimate goal of this study is to achieve a clear double-dissociation between anxiety and stress in ERP laterality. This study uses target stimuli (simple shapes) whose processing are not as right-lateralized as emotional faces. Furthermore, the design is intended to be more closely related to experimental paradigms currently being used to study anxious cognition. The spatial cuing task used in this study is adapted from that used in previous investigations of anxiety and attention (Fox, Russo, Bowles, & Dutton, 2001)(Fox, Russo, Bowles, & Dutton, 2001). Emotional face cues were used as they are more relevant for examining the cognitive effects of anxieties, as it has been shown that high anxiety individuals process threats differently than low anxiety individuals (Fox, 2002; Fox, Russo, Bowles, & Dutton, 2001), and faces are more ecologically valid than emotional words or other stimuli as we encounter them on a daily basis (Fox, Russo, Bowles, & Dutton, 2001; Kolassa &

Miltner, 2006). The paradigm previously used to examine effects on IOR following angry faces (Fox, 2002) was not included in this study as the extended SOA makes it inappropriate for examining early attentional processes of high stress individuals.

While at first intuition it may not seem so, it is postulated that both these attentional effects of anxiety and stress are adaptive in nature. The adaptive quality of early detection of threat stimuli has already been discussed (Ohman & Mineka, 2001). The delayed disengaging of attention from threat stimuli seen in high anxious individuals may represent the resolving of ambiguities of a threat. In this manner, how to most appropriately respond to the threat rather than immediately reacting can be achieved. It is predicted that this effect of "resolving ambiguity" can be demonstrated by including face cues that are 90% obscured. It is expected that such angry face cues will result in even longer delays of reaction time to invalidly cued targets than the non-obscured angry face cues in high anxiety individuals.

Other adaptations to the paradigm used by Fox and colleagues (2001; 2002) have been made. The ISI between cue and target has been shortened to 50 ms. This was done to ensure that no IOR effects would exist in the data and also to control for eye movement artifact in the ERP data. Additionally, keeping the stimulus presentation time to 150 ms will minimize saccades (thus the SOA is 200 ms which should fall within the range that elicited attentional capture in only the high anxiety individuals in Fox and colleagues' findings (2001)).

It is predicted that behaviorally, high anxiety individuals will show a delay in disengagement of attention from threat stimuli. This will be seen via slower reaction times to invalidly cued targets following an angry face cue. Additionally, this effect will be magnified in invalid trials with the obscured-angry face cues. While it is also predicted that high stress individuals will show a speeded engagement of attention to threat stimuli, this will likely not be demonstrable from the behavioral measures, as all participants should be able to engage their attention to the cued location during the 150 ms stimulus presentation. Thus, all participants should have similar reaction times to the validly cued targets. It is also predicted that psychophysiologically, anxiety and stress will be more clearly dissociable. The speeded engaging of attention to threat stimuli in high stress individuals should manifest earlier attention-related ERPs to angry faces. This may likely be demonstrated by faster latencies in the N1/P1 complex as well as the P2 component, as was found in high anxiety individuals overall by Bar-Haim and colleagues (2005). The P2 component may be larger in the high stress individuals following an angry face cue; however, it seems more likely that the high stress individuals will demonstrate a CNV effect due to their readiness to engage attention, as seems to be reflected in the aforementioned dataset. It is predicted that these ERPs will be right-lateralized, and that the P2/CNV effect will emanate from the temporal cortex. Additionally, it is predicted that high stress individuals will have a P1r component as seen in Dien (1999). High anxiety individuals are expected to have a left-lateralized N1 component as seen in Dien (1999) as well. Additionally, it is likely that anxiety will be associated with a delayed P300 component, as this component is sometimes thought to reflect disengagement of attention or making a decision, and that this component will be left-lateralized as well. It is not predicted that anxiety and stress will have overall laterality effects, but rather, specific components within each hemisphere.

2 Methods

2.1 Participants-

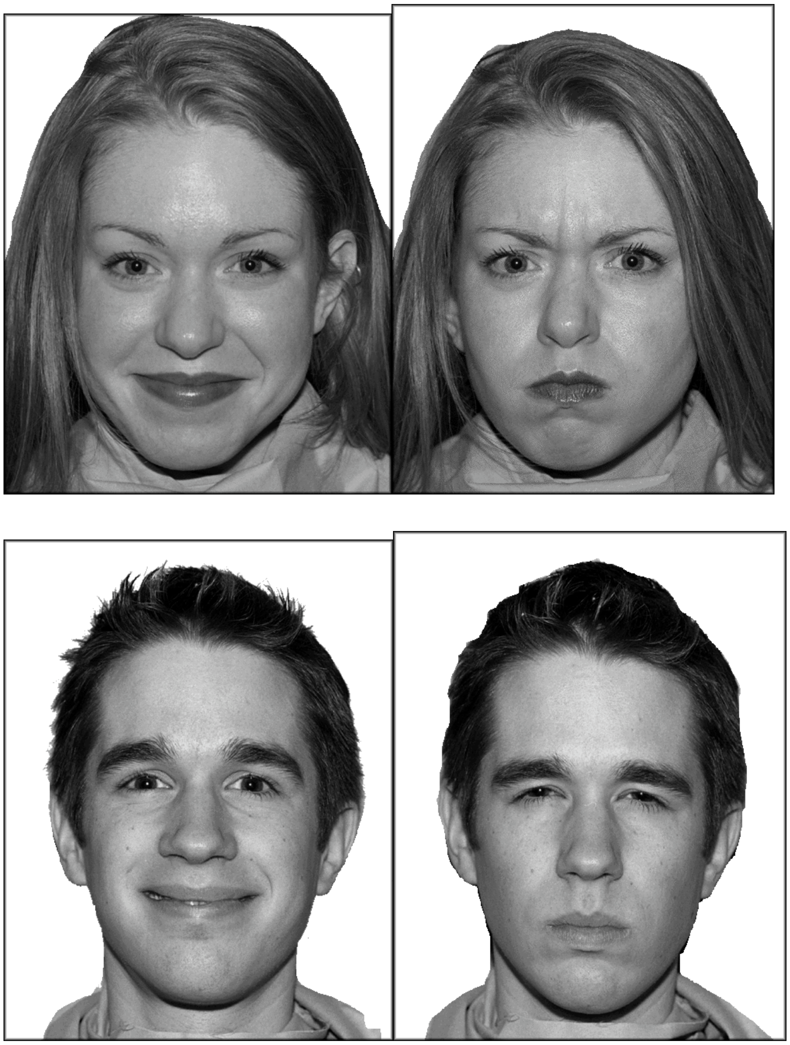
Eighty-nine right-handed, native English-speaking participants were recruited from the University of Kansas undergraduate research participant pool for this study. Participants had no history of head injury or brain pathology, were not taking any psychoactive medications and had never been diagnosed with any attention-related disorders such as attention deficit hyperactivity disorder (ADHD). Seven participants were dropped for not meeting the aforementioned prescreening requirements, eight participants were lost due to missing data (either reaction time data, EEG data, or survey data), one participant ran out of time and could not complete the study, eleven participants had too much artifact in the data to be used, and four participants were dropped for excessive blink artifact, leaving 58 final participants (30 females and 28 males; mean age of 19.7).

2.2 Stimuli-

Faces from the NimStim stimulus set were selected for this study. Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development (please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set). Eighteen faces (9 female, 9 male) were chosen from the set. All faces were

Caucasian. For each face selected, a happy and angry version of that face was used (Fig 4). Of these, both a non-obscured and an obscured version of each face was made. Thus, four versions of each face were used for the final stimulus set, each occurring an even amount of times on either side of the fixation. Faces were reduced to 90% opacity to create the obscured faces.

Figure 4. Examples of NimStim face stimuli.



The two target shapes consisted of a square and a triangle. Both targets were solid black. Both kinds of target shapes were equally as likely to be the target for any given trial. All stimuli (face cues and shape targets) were 6.4 degrees in visual angle and presented with their centers (2.5 cm from the side and 2.5 cm from the bottom) 7 cm to the left or right of the fixation on a color computer screen 41.9 cm from the participants' face, creating a total visual angle of 25.6 degrees.

2.3 Psychometrics-

To obtain measurements of anxiety, participants completed the Spielberger State-Trait Anxiety Inventory (STAI) (Spielberger, 1983). This survey is commonly used as an experimental measure of state and trait anxiety as it measures a number of cognitive, behavioral, and affective symptoms of anxiety. To obtain measures of stress, participants completed the Fear Survey Schedule (FSS) (Braun & Reynolds, 1969). This survey is commonly used to measure trait fearfulness. The version used for this study (Temple Fear Survey Inventory, TFSI) assesses fear of 100 common phobic stimuli. For both measures, participants were allowed to choose "no answer" in which case the item was scored as a missing item.

2.4 Apparatus-

Electroencephalogram (EEG) data were collected using a high-density, 128-channel EGI system with the HydroCel Geodesic Sensor Nets, version 1.0 (Electrical Geodesics, Inc.). Electrode impedances were measured using a criterion of 50k ohms, per manufacturer guidelines for this high impedance system. Data were recorded with a bandpass of .1 to 100 Hz and digitized at 250 Hz. The EEG was segmented 200 ms before the cue stimulus onset and 1000 ms after stimulus onset, retaining only trials with correct responses. EEG data were filtered using a 30 Hz lowpass filter prior to segmentation. A baseline correction was applied to the 200 ms epoch before cue onset. An average reference transform was applied to estimate the reference-independent ERP waveforms (Bertrand, Perrin, & Pernier, 1985; Dien, 1998a).

Eye blinks were removed using an automated independent components analysis routine developed by this lab (available for download at http://www.people.kul.edu/~jdien/downloads.html) using EEGLAB (Delorme & Makeig, 2004). Channels were marked bad for any given trial if the fast average amplitude exceeded 200 μv, if the differential average amplitude exceeded 100 μv, or the channel had zero variance. A channel was marked as being bad across the entire session if it was marked bad in more that 20% of the trials. Bad channels were interpolated from neighboring channels using spherical splines. Trials were marked bad if they contained more than 10 bad channels or had EOG activity in excess of 70 μv even after the ICA procedure. These automated criteria were supplemented by visual editing. Stimuli were incorporated into an E-prime (Schneider, Eschman, & Zuccolotto, 2002) experiment presentation script and were presented via a Dell Dimension 8300 PC. Computerized versions of the Spielberg State and Trait Anxiety Inventory (STAI) and the Fear Survey Schedule (FSS) were presented on the same PC via a Revolution Dreamcard stack, version 2.5 (Runtime Revolution, http://www.runrev.com/section/about_us.php).

2.5 Procedure-

Upon arrival in the lab, participants gave informed consent to participate in the study and were told that they had the right to terminate participation at any time. After net application, participants were seated in a sound attenuated room. A five-button response box was placed in front of them. Participants were instructed to use the index fingers on both their hands to press the left most and right most buttons (buttons #1 and #5 respectively). A chin rest was used to hold the participants' head steady, 41.9 cm from the presentation monitor. Verbal instructions to hold still during the experiment were issued.

Participants were instructed to keep their eyes on the fixation (a "+" sign) in the center of the screen. Their task was to discriminate between the square and triangle target shapes by pressing one button for square and one button for triangle (finger of response for which shape was counterbalanced across participants). Participants completed a practice block of 10 trials in which they received reaction time and accuracy feedback after every trial. Then stimuli were presented for four experimental blocks of 90 non-feedback trials each. A face cue appeared on one side of the fixation, and participants were told that the location of the face cue would predict where the target shape would appear "most of the time". For each trial, a fixation appeared for 1000 ms followed by the face cue presentation for 150 ms (presentations were kept under 200 ms to minimize saccades). The face cue was followed by a 50 ms ISI in which only the fixation was present. This was followed by a 2000 ms target shape presentation on either side of the fixation that terminated as soon as the participant responded.

Face cues appeared on either side of the fixation. During a valid trial, the shape target would appear in the same location as the face cue. During an invalid trial, the shape target would appear on the opposite side of the fixation as the face cue. Seventy-five percent of the trials were valid and 25% were invalid.

Between each block, research assistants checked on participants. During this time, any problem channels were re-wet. Following completion of the experimental session, participants completed computerized versions of the STAI and FSS. Finally, participants were debriefed and given an opportunity to answer any questions they may have had about the study.

2.6 Behavioral Analyses-

Accuracy scores were checked to ensure that only participants with accuracies substantially better than chance (60% correct) were included in the final analyses. None of the participants were dropped due to low accuracy. Only reaction times for correct trials that were greater than 100 ms were included in the reaction time analysis (participants only had 2000 ms to respond, so no maximum reaction time criterion was necessary). Analyses for reaction times were conducted on the median reaction time scores for each cell for each participant.

Trait and state anxiety scores were calculated separately (STAI-T and STAI-S respectively). Residualized stress scores (rFSS) on the FSS were used to adjust for the correlation between this measure and the STAI (for more information please refer to, Dien, 1999). Only the STAI-T measures were used for the analyses. Split-halves of both STAI-T and rFSS scores were used as between-groups factors for all analyses, creating four groups: high stress-high anxiety (n=15), high stress-low anxiety (n=14), low stress-high anxiety (n=14), and low stress-low anxiety (n=15). For comparison purposes, non-residualized split-half FSS scores were examined as well.

2.7 PCA ERP Analysis-

In order to isolate the primary ERP components contributing to the perception of the face cues and target shapes, a temporo-spatial PCA was conducted using the Matlab ERP PCA Toolbox 1.093 (http://www.people.ku.edu/~jdien/downloads.html). Variables for the initial temporal PCA consisted of the voltage readings at each of 275 time points (25 pre-stimulus and 250 post-stimulus). Recordings from 129 electrodes for each of the 8 conditions for each of 58 participants resulted in 59,856 observations. The relational matrix was the covariance matrix. Promax rotation was used to rotate to a simple structure (Dien, 1998b; Dien, Beal, & Berg, 2005; Hendrickson & White, 1964), with Kaiser correction for the Varimax portion of the procedure. A follow-up spatial Infomax PCA was conducted on each temporal factor score to separate them (Dien, Spencer, & Donchin, 2003; Spencer, Dien, & Donchin, 1999), using the routine from EEGlab (Delorme & Makeig, 2004). The factor scores for the 129 channels were the variables and the 8 conditions x 58 participants were the observations. Finally, the portion of the grand average accounted for by each factor was reconstructed for interpretation and analysis (Dien, Tucker, Potts, & Hartry-Speiser, 1997).

For the inferential tests, Keselman's SAS/IML code for conducting robust statistical tests (http://www.umanitoba.ca/faculties/arts/psychology/) was ported to

Matlab (http://www.people.ku.edu/~jdien/downloads). A 10% symmetric trim rule was used. The seed for the number generation was set at 1000. The number of simulations used for the bootstrapping routine was set at 50,000 to ensure stable p values. For more information regarding inferential issues with ERP data please see (Dien & Santuzzi, 2004).

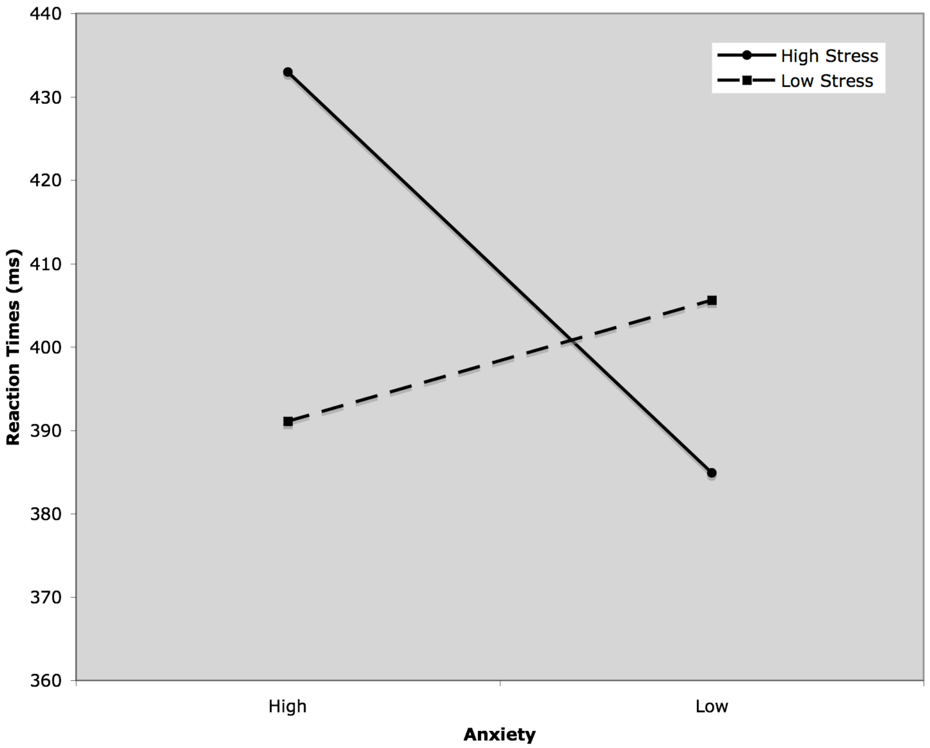
The dipole analysis was conducted with BESA (5.1.2) using a four-shell elliptical head model. The dipole pairs were constrained to have symmetrical mirror locations but free orientations. Mirror dipole pairs were used since it is common for neural activations to occur in both hemispheres, even when asymmetric. The seven periocular channels were dropped to minimize the effect of ocular artifacts. An iterative algorithm was utilized in which the program automatically shifted the position of the dipoles until it found a position of maximum fit. The analysis was conducted with three starting locations to confirm that the results were not dependent on starting location.

3 Results

3.1 Behavioral-

Trimmed arithmetic means of the individual participants' median reaction times per cell are available in Table 1. Behavioral analyses on reaction time data were 3 (non-obscured/obscured, angry/happy, valid/invalid) within by 2 (high/low trait anxiety, high/low stress) between group variables split-plot ANOVAs. A main effect for trial type, T_{WJt}/c (1, 44.98) = 38.02, $p < 0.01$, such that participants were slower to respond to invalid trials (M=410.15 ms) as compared to valid trials (M=397.14 ms) was found. A main effect for obscurity was found, T_{WJt}/c (1, 36.76) = 3.92, $p = .05$, such that individuals were slower to respond to obscured (M=405.21 ms) than non-obscured (M=4.02.09 ms) trials. Additionally, a significant interaction between trial type and obscurity, T_{WJt}/c (1, 44.10) = 28.54, $p < 0.01$, was found such that non-obscured, invalid trials had the slowest responses (M=413.19 ms) and non-obscure, valid trials had the fastest responses (M=390.99 ms). A significant interaction between trial type and face type, T_{WJt}/c (1, 40.51)=3.95, $p < 0.05$, was found such that for invalid trials, participants are slower to respond overall, but more so to angry faces (M=412.51 ms; M=407.80 ms for invalid-happy), and for valid trials participants are slower to respond to happy faces (M=397.19 ms; M=397.09 ms for valid-angry). Finally, a significant interaction between STAI-T and FSS scores, T_{WJt}/c (1, 39.88) = 5.80, $p = 0.02$, was found and is best described in Figure 5. No interactions between STAI or FSS scores were found with any of the task manipulations (cue valence, trial validity, and trial obscurity).

Figure 5. Interaction between STAI-T scores and rFSS scores.



For comparison purposes, 3 (non-obscured/obscured, angry/happy, valid/invalid) within by 1 (high/low parameter score) mixed ANOVAs were conducted separately for STAI, rFSS, and FSS scores. No significant effects for STAI and rFSS were found, however, a significant main effect for FSS on reaction times was found, $T_{WJt}/c(1, 44.9179) = 4.0516$, $p = .050$. This effect revealed that individuals whom scored higher on the FSS were slower to respond to the shape targets (M = 416.30 ms) than individuals whom scored low on the FSS (M = 391.35 ms).

Table 1. Overall mean reaction times (ms) for STAI-T and rFSS scores by task manipulation.

	NAV_a	NAI_a	NHV_a	NHI_a	OAV_a	OAI_a	OHV_a	OHI_a
$LA\text{-}LS_b$	390.10	415.23	395.08	412.92	408.15	411.15	404.46	407.85
$LA\text{-}HS_b$	372.21	391.88	370.83	394.00	387.29	393.29	386.04	383.62
$HA\text{-}LS_b$	372.88	402.50	382.67	404.29	390.88	393.67	386.21	395.71
$HA\text{-}HS_b$	423.42	452.08	420.62	432.62	431.69	440.27	431.62	431.38

[a] Column headings are: non-obscured, angry, valid; non-obscured, angry, invalid; non-obscured, happy, valid; non-obscured, happy, invalid; obscured, angry, valid; obscured, angry, invalid; obscured, happy, valid; and obscured, happy, invalid.

[b] Row headings are: low anxiety-low stress, low anxiety-high stress, high anxiety-low stress, and high anxiety-high stress.

3.2 PCA-

The Scree plot for the principal components analysis suggested the retention of 9 factors for the initial temporal PCA, accounting for 77.84% of the variance. A Scree plot suggested the retention of four factors for the subsequent spatial ICA, accounting for 80.83% of the variance. Factors were determined to be in response to the target shape if they had any trial type effects, as the validity of a trial would not be known until the presentation of the target. Analyses for the PCA factors were 4 (non-obscured/obscured, angry/happy, valid/invalid, left hemisphere/right hemisphere) within by 2 (high/low trait anxiety, high/low stress) between group variables mixed ANOVAs. A Bonferroni multiple comparisons correction was used to adjust for the comparisons over the 36 PCA factors in these ANOVAs, setting an alpha level of 0.00139.

Only one factor was found to have a significant effect following this correction. Factor 20 is a right-lateralized positivity in the posterior channels, peaking at 300 ms post-target (P296) and is greatest at channel 90 (Fig 6). A main effect for rFSS scores on P296 was found, $T_{WJt}/c(1, 36.5401) = 13.6813$, $p = .0007$. This effect revealed that P296 is larger for individuals whom score high on the rFSS (M=1.76 μv) than individuals whom score low (M = .21 μv). For comparison sake, 4 (non-obscured/obscured, angry/happy, valid/invalid, left hemisphere/right hemishpere) within by 1 (high/low parameter score) mixed ANOVAs were ran separately for each measure (STAI and rFSS) as well as for the non-residualized FSS scores. Again, none of these analyses yielded any effects with p-values that met the Bonferroni correction criterion (F20 X rFSS, $T_{WJt}/c(1, 36.2648) = 11.3117$, $p = .0016$; F20 X FSS, $T_{WJt}/c(1, 37..4401) = 5.2838$, $p = .026$; and F20 X STAI, $T_{WJt}/c(1, 43.8279) = 1.3865$, $p = .24$).

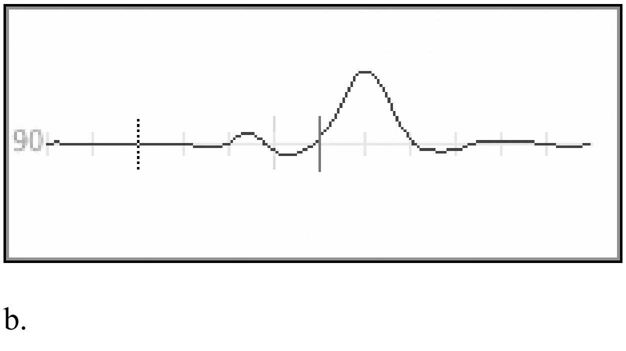
To ensure that this component found in the PCA is not a Type 1 error, a windowed analysis on the participants' individual average files was ran matching the topography and latency indicated by the PCA. Two symmetrical clusters (to facilitate laterality analysis) were chosen, centering on channels 65 and 90. A window of 300-348 ms post-target presentation was selected for the component. A main effect for laterality was found $T_{WJt}/c(1, 33.5415) = 14.0217$, $p = .0009$, such that the amplitude of the P296 was greater over right hemisphere channels (M = .89 μv) than left hemisphere channels (M = .22 μv). Additionally, an interaction between rFSS scores and laterality was found, $T_{WJt}/c(1, 33.5415) = 7.0193$, $p = .013$, such that the component is largest in the right hemisphere for high rFSS participants ($M = 1.31$ μv). This finding confirms the validity of the PCA component.

Source localization of the factor accounting for the P296 utilizing two pairs of dipoles yielded a right superior temporal gyrus location [47.0 -46.0 10.8] with a solution that accounted for 82.8% of the variance and a right inferior frontal gyrus location [37.8 39.8 -1.0] with a solution that accounted for 94.7% of the remaining variance (see Fig. 7).

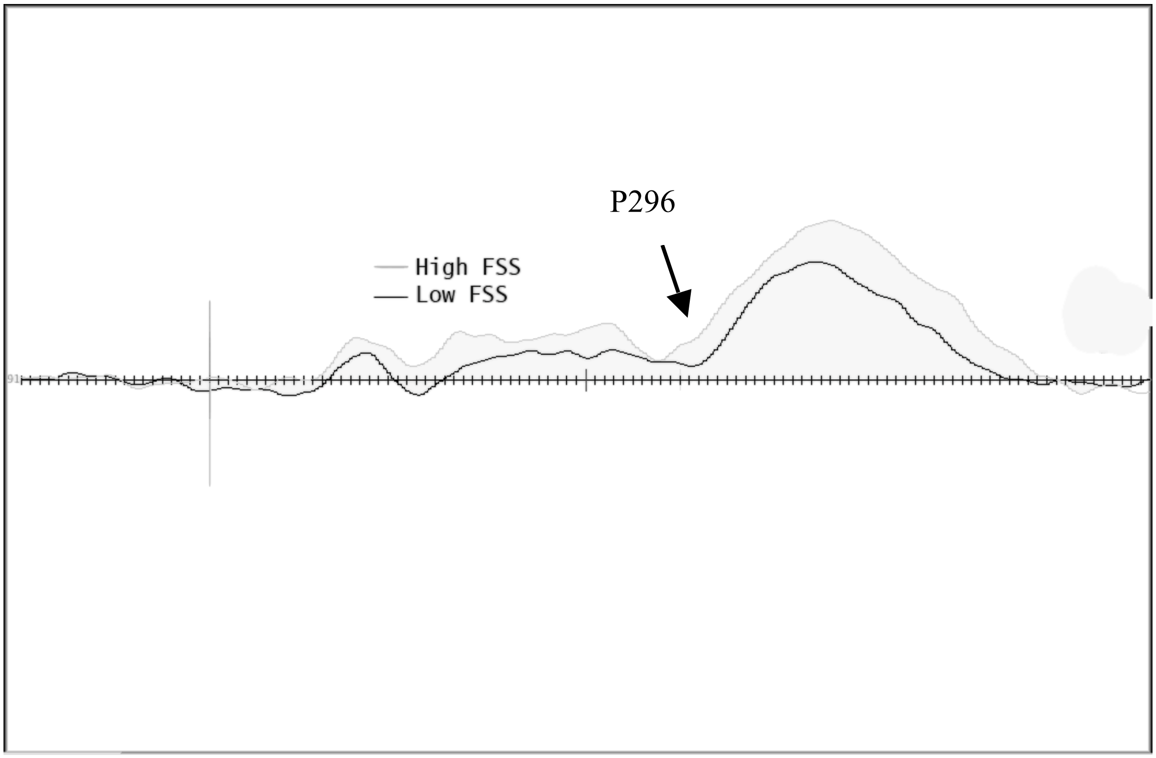
In inspecting the waveforms for high and low rFSS scores in the grand average file, it is apparent that overall, high rFSS scores result in higher amplitude recordings than low rFSS scores. To ensure that the P296 was not due to a CNV in the high rFSS group, the data was reprocessed without the baseline correction step. The resulting non-baseline-corrected grand average waveform was similar to the baseline-corrected waveform, indicating that the P296 component is, in fact, not due to a CNV effect.

Figure 6. Characterizations of the P296.

a.



b.



c.

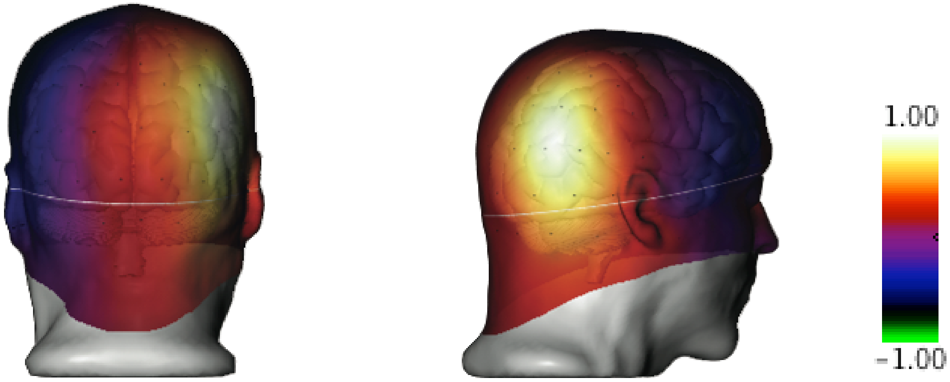
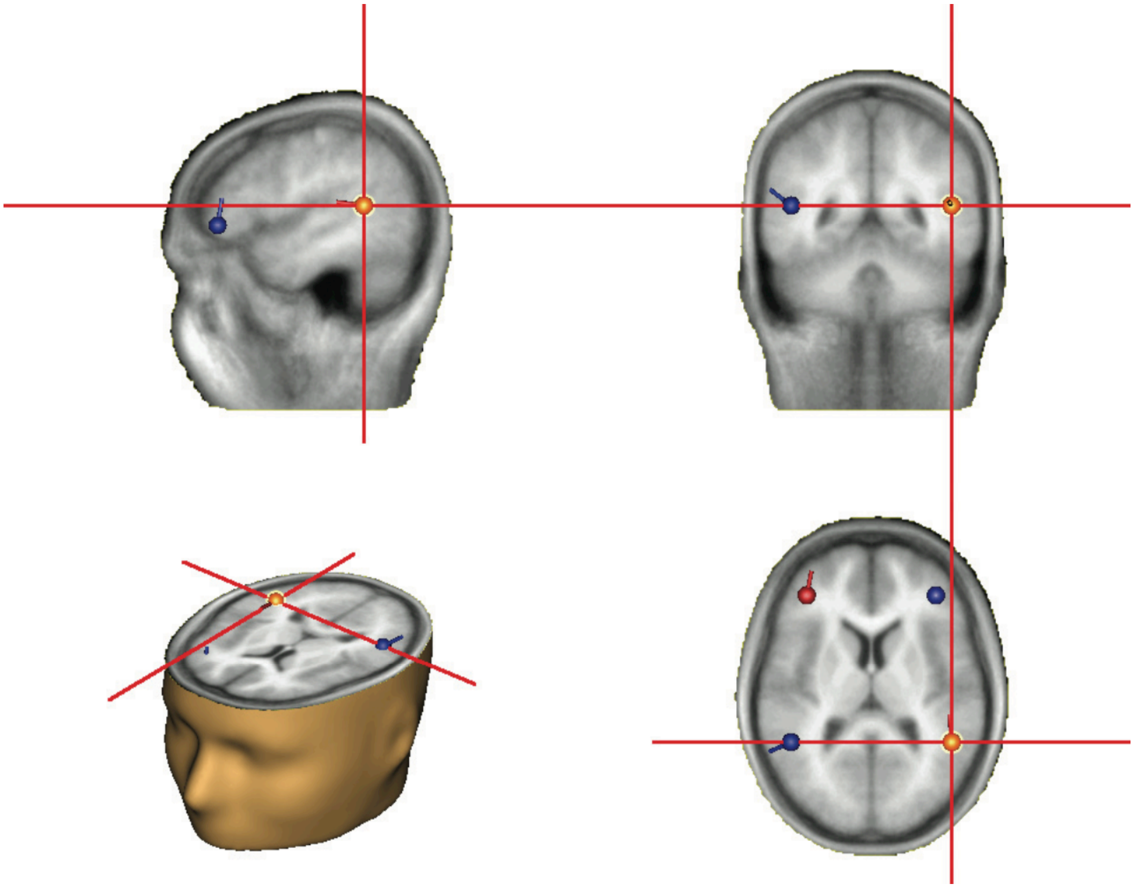
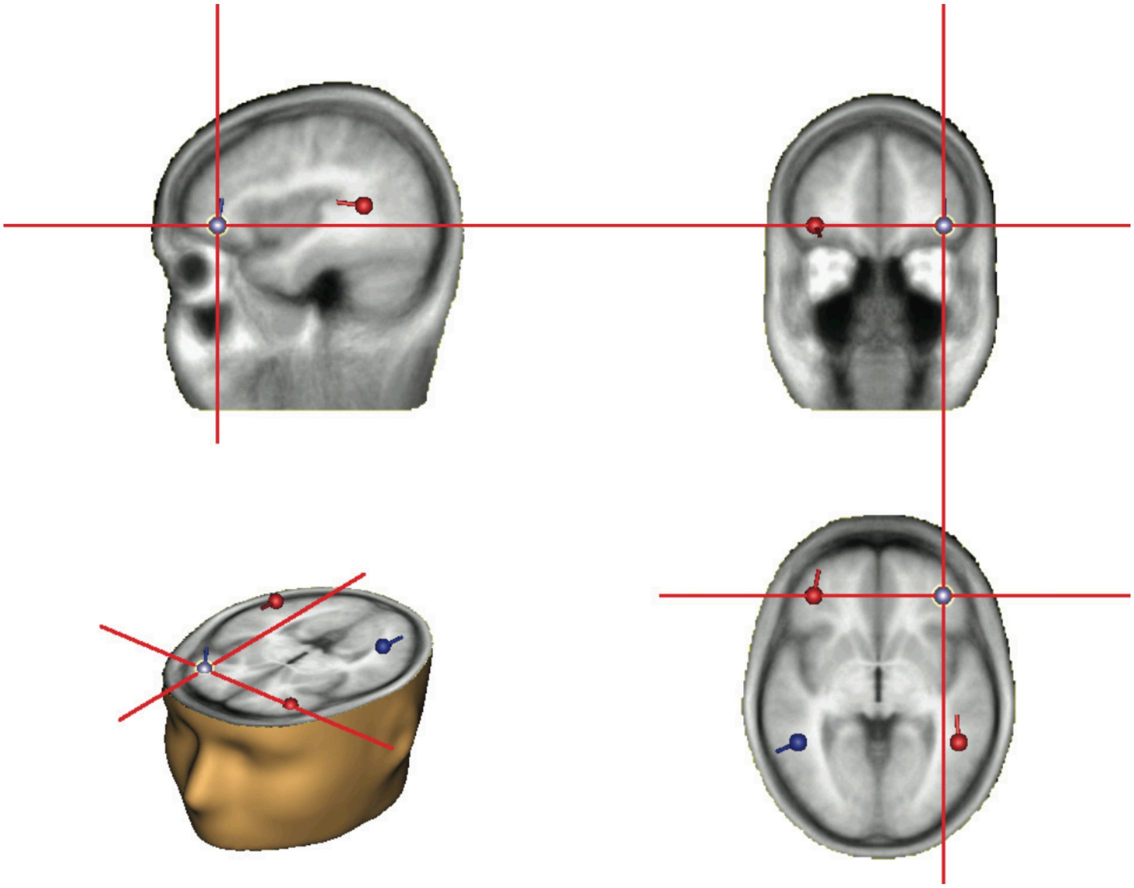


Figure 7. Results of the dipole source localization of the P296 using two dipole pairs.

a.



b.



4 Discussion

Behavioral support for high anxiety individuals experiencing a delay in disengagement of attention from threat stimuli and high stress individuals experiencing a speeding of engagement of attention to threat stimuli was not provided by the current data. No between groups variables were found to interact with the task manipulations (i.e. cue valence or obscurity or trial validity). Additionally, no ERP components were found to interact with scores on the STAI-T, thus none of the predicted components relating to anxiety were found. One component was found to interact with scores on the rFSS. This component was found to match predictions for the laterality of stress and general origin of cognition associated with stress via a dipole source localization.

A temporo-spatial principal components analysis resulted in one significant factor following correction for multiple comparisons. A CNV analysis was conducted to ensure that the effect was not due to pre-cue preparatory effects in the high rFSS group. This factor was a right-lateralized posterior positivity occurring 296 ms post-target presentation. This component is most closely centered on PO8 (within 2 cm) in the 10-10 System (Luu & Ferree, 2005). While this component was not modulated by any of the stimuli conditions (target validity, cue valence, or cue obscurity), it was modulated by the participant scores on the Fear Survey Schedule (FSS), in that its amplitude was greater for high FSS scores than low FSS scores. There were no effects of State-Trait Anxiety Inventory (STAI) scores on this component. This result gives partial support for the dual-anxiety models and separate lateralities for anxiety and stress. In addition, this result gives credence to using the FSS as a more sensitive measure for stress than the STAI. Behavioral results supported expected main effects of the stimuli conditions with reaction times being slower to invalidly cued targets and following obscured cues. Nonetheless, no between groups effects were found to modulate reaction times, except that individuals who scored high on the raw FSS were found to respond more slowly overall than individuals who scored low on the raw FSS, but the raw FSS cannot be considered an independent measure of stress as it shared a .25 correlation with the STAI.

While the resulting ERP component did not respond to task manipulations, it still can be considered informative. It is likely that the paradigm used in this study was inappropriate for eliciting the task effects desired, as indicated by the lack of between group effects on reaction times. Indeed, others have had difficulty getting salient task manipulation effects with between group factors in similar paradigms, with the most prominent studies only getting a marginally significant effect (p = .054) (Fox, Russo, Bowles, & Dutton, 2001) and a statistical trend (p = .06) (Fox, 2002) and others only getting effects for high and low anxiety in general but not interacting with task manipulations (Bar-Haim, Lamy, & Glickman, 2005). The correct paradigm for eliciting the desired attentional effects of stress and anxiety is thus proving to be difficult to establish, as this study too found no effects for individual differences interacting with task manipulations, and thus no support was found for Fox and colleagues' (2001; 2002) theory of delayed attentional disengagement from threats in high anxiety individuals.

Regardless of the lack of between-groups effects on the behavioral data, the main goal of this study, to discriminate between anxiety and stress, was partially accomplished in the ERP analysis. As expected, a right-lateralized ERP was found to be sensitive to levels of stress. The laterality of this finding matches previous findings for dual-anxiety laterality models (Dien, 1999; Engels et al., 2007; Heller, Nitschke, Etienne, & Miller, 1997). Unfortunately, however, no double-dissociation between stress and anxiety was supported by the data for this study.

While the P296 is not identical to the P1r reported in Dien (1999), the similarities between the two components bear discussion. The P1r component previously reported was also amplitude-sensitive to scores on the FSS with its amplitude being greater for high scores than low scores. Additionally, the P1r appeared 300 ms post-stimulus (there was only one stimulus for this study rather than a cue and target stimulus), while the P296 reported here appeared 300 ms post-target. The P1r was located more frontal-centrally than the P296; however, some of the differences in topography may be due to the movement of the stimuli used previously, as this has been shown to modulate the location of some ERP components (Kennett, van Velzen, Eimer, & Driver, 2007; Van der Stigchel, Heslenfeld, & Theeuwes, 2006). The current study did not find any ERPs to correlate with STAI-T scores or the N1 previously reported by Dien (1999). The lack of findings for STAI-T scores may be due to the nature of the study (the emotional face stimuli) being enough to arouse high stress individuals but not high anxiety individuals.

Additionally, the P296 provides more information for the P2 component reported to be modulated by levels of anxiety as measured by the STAI-T (Bar-Haim, Lamy, & Glickman, 2005). As discussed earlier, the waveforms producing the P2 in this study appeared to possibly be due to a CNV effect early in the data. This was also true for the waveforms in the current study; however, after controlling for possible CNV effects by reanalyzing the data with out the baseline correction, no CNV effects were found. Thus, it is also likely that the P2 effect found for high anxiety individuals is also a true component and not due to a CNV effect. It is important to remember that the P2 effect was reported for scores on the STAI-T and the P296 effect was found for scores on the rFSS, thus they are not likely reflecting the same cognitive aspects of the same type of anxiety.

The current study also did not replicate the P1 component previously found to correlate with FSS scores in social phobics (Kolassa & Miltner, 2006). The P1 is thought to reflect early visual attention, and thus the ability of social phobics to quickly detect stimuli in their environment. Again, the difference in participants could account for the difference in findings here.

The P296 found in this study also resembles a P340 component found in a similar paradigm (Carretie, Martin-Loeches, Hinojosa, & Mercado, 2001). In this study, images of varying arousal levels and valence were displayed in a similar probe detection task in which cues were presented bilaterally, and targets were either validly or invalidly cued. Again, a PCA resulted in a P340 component that was larger in amplitude to high-arousing positive images than low-arousing positive, high/low-arousing negative, neutral, and relaxing images. This component was centered on P6 and source localized to the visual association cortex. It was interpreted as representing input-processing related attentional processing (Posner & Raichle, 1995) following the presentation of the target. Again, the topography of this component with the P296 is not identical; however, as the EGI Hydrocel nets, as used in this study, only provide close approximations of matching channels to the 10-10 system, the possibility of these two components being very close in topography exists. Few other studies have looked at dual-anxiety or stress models with ERPs; however, the

P300 component has been shown to be right lateralized regardless of field of cue presentation (Alexander et al., 1995; Muller & Knight, 2002), and spatial information processing has been found to be right lateralized as well (Jonides et al., 1997; Pardo, Fox, & Raichle, 1991). Thus, both of these effects could most parsimoniously explain the right-lateralized component occurring 300 ms post-target found here.

The first source indicated by the dipole-source localization, the right superior temporal gyrus (rSTG), is in agreement with an area previously found to be sensitive to measures of anxious arousal (Engels et al., 2007), thus support is provided for updating the original model of anxious apprehension emanating from the left frontal cortex and anxious arousal emanating from the right posterior parietal cortex to include anxious arousal emanating from the right temporal cortex as well. This area is also of interest as it borders the right temporoparietal junction, an area indicated in the detection of targets (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000). Additionally, a dipole source localization is typically deeper than the distributed activation it represents, thus the rSTG solution is more likely emanating from the parietal cortex. As it is predicted that high stress individuals would be better primed to detect threats in their environment, it fits that they would show a greater activation in this area of the brain than low stress individuals. A parietal source for the P296 also fits within the predictions of Heller and colleagues' dual-anxiety model (Heller, Nitschke, Etienne, & Miller, 1997). The second source indicated by the dipole-source localization is the right inferior frontal gyrus (rIFG). For the same reasons as stated above, this source is more likely emanating from the orbitofrontal cortex. This is a region that has repeatedly been shown to be involved in the processing of emotional stimuli (see (Adolphs, 2002) for a review). Again, the source-analysis conducted for the P296 provides only a rough estimate of its source location.

The cue stimuli used for this study were angry and happy faces; therefore it is interesting that classic face-processing ERP components were not present. The N170 is an ERP component that has been argued to represent the recognition of a face (Eimer, 2000; Sagiv & Bentin, 2001). It is typically a right-lateralized component in the posterior of the head and is thought to originate in the fusiform gyrus (Vuilleumier, Armony, Driver, & Dolan, 2001; Vuilleumier & Schwartz, 2001). Evidence in the literature does exist for task modulation to diminish the N170 face-recognition response, however (Galli, Feurra, & Viggiano, 2006; Goffaux, Jemel, Jacques, Rossion, & Schyns, 2003). One study found that negatively valenced faces resulted in diminished N170s (Galli, Feurra, & Viggiano, 2006), while another study found that increasing task demands also diminish the N170 (Goffaux, Jemel, Jacques, Rossion, & Schyns, 2003). As the paradigm in this study included negative faces as well as a task additional to processing the face cues (categorizing the shape of the target), it is likely that the N170 response was diminished enough to no longer be salient enough to extract from the ERP waveforms. Indeed, another study using a probe-detection task with face cues failed to find an N170 response (Bar-Haim, Lamy, & Glickman, 2005).

Another possible explanation for the P296 result is that it is an indicator of the differences between the FSS and the STAI. The fact that this component was only sensitive to FSS scores and not STAI scores does seem to suggest that these two psychometrics are measuring different emotional constructs, though no clear dissociation was provided by this data. If nothing else, it seems that the FSS is measuring a different aspect of anxiety than the STAI, and thus would be a more appropriate measure than the STAI for assessing levels of high-arousal in anxious individuals, as items for this survey examine various aspects of fear, and the component it associates with is over an area previously presumed to house anxious arousal (Heller, Nitschke, Etienne, & Miller, 1997).

Commonly, the STAI is used as an assessment of levels of stress and anxiety together in an individual. This measure asks the same questions for how an individual is feeling now (state mood) and how an individual feels in general (trait mood). Less often, the FSS is used as a measure of fear or stress. This measure has several versions, with items that assess the amount to which an individual is frightened of something. A search on PsycINFO yielded 3843 citations that utilized the STAI, while a search for the FSS yielded only 510 citations. It is likely that the FSS would be a more appropriate tool than the STAI for researchers who are interested in studying the hyper-vigilance to threat stimuli seen in high stress or hyper-arousal anxious individuals.

Indeed, at least one other study has found ERP effects only for the FSS and not the STAI (Kolassa & Miltner, 2006) in a clinical population. In a paradigm in which participants were to classify either the gender or the valence (angry, neutral, happy) of facial stimuli, higher FSS scores were correlated with greater P1 amplitudes in right posterior sites of social phobics. While the clinical population studies here makes this finding difficult to generalize to sub-clinical levels of stress, it does provide support for the FSS measuring stress independently of the STAI (social phobics completed both surveys and no effects were found for the STAI).

The initial goals for this study, to dissociate between stress and anxiety behaviorally, cognitively and electrophysiologically, may have been too ambitious for what has already been accomplished in this field. As has already been mentioned, solid behavioral results via reaction times have not been reliably established (Fox, 2002). Therefore, it would likely be best to step back from the electrophysiological recordings until a paradigm has been worked-out that can accomplish this. Once a paradigm has been established that reliably elicits the behavioral results expected: high STAI scores correlating with delayed responses to invalid-angry trials and high FSS scores correlating with speeded responses to valid-angry trials, it would then be appropriate to return to ERP methodologies to establish separate lateralities for anxiety and stress.

In order to more accurately study the laterality effects of interest, several other changes to the current paradigm would be appropriate. First, as a left-lateralized effect for anxiety is expected, it would be better to use negative valenced stimuli that are not faces, as faces are known to be specially processed in the right hemisphere as indicated by activity in the right fusiform gyrus (Sergent, Ohta, & MacDonald, 1992) and the N170 component (Bentin, Allison, Puce, & Perez, 1996). Thus, it is likely that the face cues used in the current study may have masked any left-lateralized activity that was occurring. Additionally, a paradigm that utilized central presentations rather than lateral would help to rule out if known ERP components' topographies are moving as a result of the location of the stimuli. As well, a paradigm in which the face cue was present during the presentation of the target would better serve examining any gluing of attention effects. Finally, a longer SOA would be more appropriate for this paradigm so that ERPs associated with the cue and ERPs associated with the targets could be better characterized, as the short SOA used in the current study made it likely that there was overlap between the two. The P296 component found here does have interesting implications fro research on anxiety; however, the nature of its main effect for FSS scores makes it difficult to interpret the cognitive function of this component. Further directions would include more closely examining the effects of target detection in this high stress group.

4.1 Conclusions-

The right-lateralized P296 component found to be higher in amplitude to high stress individuals than low stress individuals matches the predictions of the dual-anxiety model proposed by Heller and colleagues (1997) and Dien (1999). However, no evidence for stress and anxiety being completely dissociable emotional constructs was provided by these data. The lack of between groups effects in the behavioral data indicate that the paradigm used for this study needs amending to better elicit the expected effects of the task manipulations.

Nonetheless, the P296 is located over the temporopariental region; an area of the brain implicated in target detection (Corbetta, Kincade, Ollinger, McAvoy, &

Shulman, 2000) and input-processing related attentional processes (Carretie, Martin-Loeches, Hinojosa, & Mercado, 2001). It is likely that the P296 indicates that high stress individuals are more primed to detect targets in their environment than low stress individuals, as indicated by the increase in amplitude in the P296. This result, again, has implications for the dual-anxiety models as well as for indicating that the FSS may be a more sensitive psychometric for measuring stress levels than the STAI.

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