THE TIME COURSE OF ATTENTIONAL BIAS IN ANXIETY

BY

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DISSERTATION

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ABSTRACT

Attentional bias to emotional stimuli (especially unpleasantly valenced or threatening) is a common finding in anxiety and less commonly found in depression. So-called neutral or “non-emotional” stimuli varying in attentional processing demands have not been systematically investigated or contrasted with emotional stimuli. In order to clarify the specificity of early sensory attentional prioritization of emotionally arousing stimuli in anxiety, the present project investigated event-related potentials (ERPs) during the emotion- and color-word Stroop tasks in both anxious and depressed participants. Present data show that emotional information is not always preferentially processed in anxiety and depression and that preferential processing may depend on the processing demands of neutral stimuli. Systematic examination of the role of emotional valence, emotional arousal, and neutral and emotional stimulus processing demands is crucial to understanding so-called “preferential” attention for emotional stimuli in anxiety, depression, and comorbidity. Such work can yield insights into cognition-emotion interactions in psychopathology that may improve understanding of the etiology and treatment of these disorders.
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CHAPTER 1
INTRODUCTION

Emotional disturbances are common in nearly all types of psychopathology, including mood and anxiety disorders (Berenbaum, Raghavan, Le, Vernon, & Gomez, 2003). What is sometimes called the cognitive approach to understanding and treating emotional disorders has focused almost exclusively on biased emotional information processing as an etiological and maintaining factor in various forms of psychopathology, including anxiety disorders (e.g., Beck, Emery, & Greenberg, 2005; Williams, Mathews, & MacLeod, 1996). A large body of research has demonstrated that anxiety is characterized by cognitive biases and impairments (for reviews, see Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007; McNally, 1998), particularly an attentional bias to threatening stimuli (Compton, Heller, Banich, Palmieri, & Miller, 2000; Nitschke & Heller, 2002). This phenomenon has been demonstrated in state and trait anxiety (Egloff & Hock, 2001) as well as in every anxiety disorder diagnosis in DSM-IV-TR (American Psychiatric Association, 2000).

Many of the studies demonstrating attentional bias in anxiety have relied on stimuli with an emotional dimension. Fewer studies have systematically investigated non-emotional (“neutral”) stimuli. The possibility has been raised that anxious participants have fewer cognitive resources available for tasks due to a preoccupation with negative or anxious thoughts (Eysenck, 1997). Consistent with this idea, anxious participants have shown a general difficulty maintaining attentional focus in the face of threatening (e.g., see Eysenck, 1997) and “neutral” material (Fox, 1993). For example, Fox (1993) found that high trait anxiety was associated with a general deficit in inhibiting distracting information whether or not the information was
emotional. She speculated that failures to control attentional focus may explain more general deficits in concentration and memory reported by anxious participants.

The specificity of attentional processing of emotional stimuli in anxiety is unclear, given existing literature. “Non-emotional” or neutral stimuli varying in attentional processing demands have not been systematically investigated or contrasted with “emotional” stimuli in the anxiety literature. Resolving this issue is critical to understanding attention abnormalities in anxiety, especially regarding threatening stimuli and whether this bias generalizes to more cognitively demanding stimuli without an explicit emotional dimension. Resolution of this issue has implications for supporting and/or refining the hypothesis that preferential attention to threatening stimuli is an etiological and maintaining factor of anxiety.

Although cognition and emotion have been conceptualized and are often discussed as though they are separate constructs, it is not assumed in the present text that these are independent constructs but rather that they interact and effectively merge in many contexts. Thus, distinguishing between “cognitive” and “emotional” stimuli in the present text is not meant to imply that one’s emotional state does not impact the way neutral stimuli are processed, nor that one’s cognitive abilities do not impact the way in which emotionally valent stimuli are processed. Indeed, some research suggests that cognition and emotion can be integral or difficult to distinguish (e.g., Davidson, 2002; Gray, 2004; Gray, Braver, & Raichle, 2002; Heller & Nitschke, 1998; Herrington et al., 2005; Miller, 1996; Mohanty et al., 2005). Stimuli with an explicit emotional valence at higher levels of arousal will be referred to in the present text as “emotional” (e.g., emotion words such as “murder” or “joy” in the emotion-word Stroop task), and stimuli without an explicit emotional dimension will be referred to as “non-emotional” (e.g.,
color words such as “green” written in red ink or “red” written in red ink in the color-word Stroop task).

Attentional Bias to “Emotional” Stimuli in Anxiety

The seemingly ubiquitous finding of attentional bias to threat across various forms of anxiety is qualified by four important issues. First, pleasant stimuli are frequently not included in investigations of attentional bias to threat, so emotional valence may be a confound. That is, it may not be threat in particular that draws attention, but any emotionally intense stimulus. Second, when pleasant stimuli are included, they are not always matched to threatening stimuli on perceived arousal, nor are arousal levels always reported for emotional stimuli, so emotional arousal may be a confound. Failure to report arousal qualities of stimuli is problematic, because emotional arousal may be important in attracting attention (Keil, Bradley, Hauk, Rockstroh, Elbert, & Lang, 2002). Indeed, the prominent circumplex model of emotion decomposes emotion into two basic dimensions, valence and arousal (e.g., Barrett & Russell, 1999; Lang, Bradley, & Cuthbert, 1990). Further, research on neural processing in emotion has identified arousal as a critical factor in recruiting brain regions, such as right occipitotemporal regions (e.g., Compton et al., 2003) and amygdala (e.g., Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). It is therefore important to consider both dimensions as potential contributors to attentional bias. Including pleasant stimuli that are matched to threatening stimuli on arousal value is necessary in order to demonstrate the specificity or generality of attentional bias to threat in anxiety. Third, when pleasant stimuli have been included in previous investigations, a lack of attentional bias toward threat specifically has been found in some anxiety disorders, such as generalized anxiety disorder (e.g., Becker, Rinck, Margraf, & Roth, 2001; Martin, Williams, & Clark, 1991), but not consistently in other anxiety disorders, such as social phobia (e.g., Becker et al., 2001).
Explaining this inconsistency and whether it is due to an emotional arousal confound may facilitate identifying mechanisms of attentional bias in anxiety.

Fourth, gender has not been systematically considered in the attentional bias literature. Lifetime prevalence rates of anxiety are estimated to be higher than any other class of psychological disorder (Kessler et al., 2005), and women are estimated to be affected by anxiety disorders more than men, with some estimates as large as 2:1 (Craske, 2003). Despite these striking gender differences in rates of anxiety disorders, gender has not been consistently assessed in investigations of contributors to the development and maintenance of anxiety disorders, leaving open the possibility of gender differences in attentional bias in anxiety. This would be important to identify in its own right and may illuminate general mechanisms. In addition, gender has been shown to be important in neural processing of emotional stimuli. For example, gender modulates amygdala activation, and the amygdala is one of the most well-established brain structures to play a role in emotion (Cahill, 2006). This brain region is also activated more broadly by emotionally arousing stimuli (not only by negative stimuli; e.g., Garavan, Pendergrass, Ross, Stein, & Risinger, 2001; Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005).

Gender may also be an important factor in reconciling seemingly contradictory findings in processing patterns in nonanxious controls. In an fMRI study investigating processing of emotional pictures in control participants, women showed greater activity in primary and secondary visual areas to unpleasant than pleasant pictures (Lang et al., 1998), whereas men tended to show greater visual-area activity to pleasant than unpleasant pictures, especially erotic pictures (Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004; Lang et al., 1998). In addition, women rated unpleasant pictures as more unpleasant and more arousing than men in
combination with showing larger changes in corrugator EMG (frown-associated muscle) activity while viewing unpleasant pictures (Bradley, Codispoti, Sabatinelli & Lang, 2001). Conversely, men rated pleasant (especially erotic) pictures as more arousing than unpleasant pictures and responded with more skin conductance (sweat gland) activity (Bradley et al., 2001; Bradley & Lang, 2007). If women preferentially process threat, whereas men preferentially process pleasant stimuli at higher levels of arousal, failing to examine gender would lead to unnecessary inconsistency across samples. A better understanding of the nature and time course of male and female non-anxious participants’ allocation of attention to emotional stimuli may have important treatment implications and may aid in understanding the higher prevalence rates of anxiety disorders in women (see also Narrow, First, Sirovatka, & Regier, 2007).

Four prominent possibilities have been explored regarding the timing of attentional bias to emotional stimuli in anxiety. Three of these hypotheses have focused on threat and none has systematically considered gender. First, attention may be captured quickly and automatically by threatening stimuli in a variety of paradigms, including tasks in which masked emotional stimuli are conditioned without conscious awareness, or visual search tasks in which biologically threat-relevant stimuli such as snakes and spiders are detected more rapidly than flower or mushroom stimuli (Öhman & Soares, 1998; Öhman, Flykt, & Esteves, 2001; Williams et al., 1996). Second, it may be difficult to disengage from threatening stimuli. This hypothesis has been investigated using spatial attention tasks in which a threatening cue stimulus is flashed to the left or right side of visual space, followed by a non-threatening target to which the participant is supposed to respond. When the target is flashed to the side of visual space opposite to a threatening cue, performance is slowed, suggesting preferential prolonged engagement with threatening stimuli (e.g., Fox, Russo, & Dutton, 2002). Third, there is evidence that threatening
stimuli can be initially engaged, followed by avoidance, known as the vigilance-avoidance hypothesis (Mogg, Mathews, & Weinman, 1987). For example, trait-anxious individuals show attentional bias to threat in a visual probe task at a shorter stimulus duration (e.g., 500 ms) in the absence of evidence for prolonged engagement with the stimulus at longer stimulus durations (e.g., 1500 ms; see Mogg, Bradley, Miles, & Dixon, 2004).

Finally, the emotionality hypothesis, although not cast in terms of emotional arousal, holds that emotional stimuli in general will draw attention relative to neutral stimuli (e.g., Martin et al., 1991), although attentional biases to threatening versus pleasant stimuli may develop over different time frames (Bradley, Mogg, White, Groom, & de Bono, 1999). The present study investigated the time course of attentional processing of emotional stimuli in order to evaluate and expand upon these possibilities.

*Emotion-word Stroop task*

Many studies have used a modified Stroop task, called the emotion-word Stroop task, to establish and investigate attentional bias in anxiety. The content of the distracter words is threatening ("die"), neutral ("sum"), or pleasant ("joy"). Participants must respond to the color of the word while ignoring the content or meaning of the word. Many studies (reviewed by Koven, Heller, Banich, & Miller, 2003; Nitschke & Heller, 2002; Williams et al., 1996) demonstrate that color naming is slowed in both anxious and non-anxious participants when the distracter word is threatening. Reaction time to threatening words is typically much slower for anxious individuals, suggesting that they have more difficulty than non-anxious individuals in filtering out threatening information, even when task-irrelevant.

In evaluating when and how attention is deployed to emotional stimuli, research has relied heavily on dependent measures (such as reaction time) that do not allow continuous
measurement of attentional processing across time. Unlike reaction time, event-related brain potentials (ERPs) offer millisecond-by-millisecond measurement of attentional processes. Surprisingly few studies have used ERP measures while investigating attentional bias to emotional stimuli in anxiety.

The present project employed ERPs to investigate the time course of attentional bias in an emotion-word Stroop task (the same components were used to contrast the emotion-word with the color-word Stroop task, discussed later). Specifically, P100 and N200 ERP components were examined to explore the question of the onset of attentional bias. P100 is a positive-going voltage fluctuation peaking approximately 100 ms after stimulus onset, likely originating from extrastriate areas of visual cortex and maximal over occipital regions for visual stimuli. As more attention is allocated to a visual stimulus, more extrastriate neurons are recruited to process the stimulus, and P100 amplitude increases (e.g., Luck, Woodman, & Vogel, 2000). In a task where a neutral and an emotional face pair were flashed simultaneously on the left and right side of visual space, followed by a horizontal or vertical bar flashed to the left or right side replacing one of the face stimuli, P100 was larger when the bar replaced a fearful face than when it replaced a neutral face (Pourtois, Grandjean, Sander, & Vuilleumier, 2004), suggesting that P100 can be sensitive to fear stimuli. N200 is a negative-going voltage fluctuation over posterior regions for visual stimuli. N200 peaks roughly 150-250 ms post-stimulus and has been associated with involuntary stimulus discrimination and classification (Näätänen, 1990; Nobre, Allison, & McCarthy, 1998; Ritter, Simson, Vaughan, & Macht, 1982) and abstract linguistic processing (Grossi & Coch, 2005). It has been noted in studies involving processing of emotional content (Deldin, Keller, Gergen, & Miller, 2000; Kayser, Bruder, Tenke, Stewart, & Quitkin, 2000;
P300 and N400 components are potentially valuable for assessing later processing of emotional material. The traditional P300 (sometimes called P3b, late positive potential, LPP, or late positive complex, LPC) has a predominantly parietal distribution, peaking approximately 300-600 ms post-stimulus. P300 amplitude is associated with increased resource deployment (e.g., Yee & Miller, 1994) and is thought to reflect context updating and event categorization processes (e.g., Coles, Gratton, & Fabiani, 2000; Donchin & Coles, 1988). P300 is often larger for emotional than for neutral picture or word stimuli (e.g., Fischler & Bradley, 2006; Herbert, Junghöfer, & Kissler, 2008; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997; Schupp et al., 2004), reflecting prioritization of emotion processing. P300 latency is often independent of the timing of response-related motor processes and can serve as a more specific measure of stimulus evaluation duration (Donchin & Coles, 1988; Duncan-Johnson & Donchin, 1982).

N400 is a negative-going waveform, commonly seen in response to words, that is modulated by semantic meaning, with larger amplitude associated with improbable words and smaller amplitude associated with facilitated processing (e.g., for words of higher lexical frequency or words “primed” in a given sentential context; Federmeier, Kirson, Moreno, & Kutas, 2001; Kutas & Hillyard, 1980; van Petten & Kutas, 1990). N400 amplitude is reduced for emotional stimuli that are primed. For example, emotional words congruent with prosody elicit smaller N400 than do those incongruent with prosody (Schirmer, Kotz, & Friederici, 2002, 2005). Emotional words have also been shown to elicit smaller N400 than neutral words in the context of a lexical decision task (judge whether the current stimulus is a word or non-word).
where no explicit “priming” of emotion was conducted, though emotional and neutral words were presented in blocks (Kanske & Kotz, 2007).

A small but growing number of studies are using ERPs to investigate the emotion-word Stroop task in non-clinical adult samples (e.g., Li, Zinbarg, & Paller, 2007; van Hooff, Dietz, Sharma & Bowman, 2008) using unpleasant and neutral (but not pleasant) words. van Hooff et al. investigated two ERP components in an unselected sample, P100 (maximal over occipital sensors) and “negative slow wave” (NSW; similar to N400, with maximum over frontal/frontocentral sensors). Unpleasant words were associated with larger P100. There was no main effect of valence for NSW at 300-700 ms. Instead, this component became more negative for a subset of unpleasant words that produced RT interference. These findings were interpreted as evidence for both early (larger P100 for unpleasant than neutral words) and later (larger NSW for a subset of unpleasant words than neutral) preferential attentional processing of unpleasant stimuli.

More directly related to the present project, Li et al. (2007) included individuals high or low in trait anxiety (as measured by the Behavioral Inhibition Scale, Carver & White, 1994) in an emotion-word Stroop task with neutral and threat words. Enhanced occipital P100 to threat words was found for both “subliminal” and supraliminal presentation rates. The P100 effect was more pronounced as trait anxiety increased. P300 amplitude prompted by threatening words was moderated by trait anxiety only in the subliminal condition, with higher trait anxiety associated with larger P300 to threatening words. Taken together, these ERP studies using emotion-word Stroop tasks suggest that unpleasant words prompt preferential processing at both early and later stages in anxiety. However, in the absence of pleasant words, these findings are not a test
specifically of whether emotional valence or emotional arousal is preferentially associated with attentional bias.

In apparently the only ERP study to examine the emotion-word Stroop in adult patients (Metzger, Orr, Lasko, McNally, & Pitman, 1997), individuals with PTSD had smaller P300 across all word types (personal pleasant, neutral, and personal traumatic) than healthy controls. However, within the PTSD group, P300 was larger to both pleasant and traumatic than neutral words, suggesting more resource deployment to arousing words generally, not just to trauma words, in line with P300 results reviewed above. A trend was also observed for longer P300 latency to trauma-related words in patients with PTSD, suggesting longer evaluation time for threatening stimuli. These findings suggest that timing distinguishes both psychiatric status and emotional valence. To further capitalize on the potential of the emotion-word Stroop paradigm, the present project examines ERPs in carefully selected groups of anxious participants to elucidate the time course of attentional bias to emotional and non-emotional stimuli.

Dimensions of Anxiety

Anxiety is a broad, heterogeneous construct that is sometimes (but often problematically) treated as a unitary phenomenon (Lang, 1968; Miller & Kozak, 1993). However, anxiety can be analyzed in terms of at least two distinct dimensions, anxious apprehension and anxious arousal. Anxious apprehension is primarily characterized by worry and verbal rumination (Barlow, 1991; Heller, Nitschke, Etienne, & Miller, 1997), whereas anxious arousal is characterized by somatic tension and physiological arousal (Clark & Watson, 1991). Although these two types of anxiety are not mutually exclusive and may both be present to varying degrees in different disorders, anxious apprehension is prominent in generalized anxiety disorder and obsessive compulsive disorder, and anxious arousal is prominent in panic attacks and high-stress situations (Nitschke,
Heller, & Miller, 2000). These two dimensions of anxiety are also distinguished by different patterns of lateralized brain activity.

EEG and fMRI studies indicate that individuals scoring high on measures of anxious apprehension show greater activity over the left than right hemisphere (Engels et al., 2007; Heller, Nitschke, Etienne et al., 1997). The left hemisphere has been implicated in studies of obsessive-compulsive disorder (e.g., Baxter, Phelps, Mazziotta, Guze, Schwartz, & Selin, 1987; Swedo et al., 1989), generalized anxiety disorder (for a review see Nitschke & Heller, 2002, 2005; Wu, Buchsbaum, Hershey, Hazlett, Sicotte, & Johnson, 1991), and trait anxiety (Tucker, Antes, Stenslie, & Barnhardt, 1978), conditions marked by high levels of anxious apprehension. These findings linking the left hemisphere to anxiety disorders that feature worry and anxious apprehension are consistent with its specialization for language. Thus, anxiety-related impairments in various tasks might be accounted for by interference from iterative activity in left-hemisphere verbal processing circuits.

In contrast, anxious arousal shows more right than left lateral frontal activity coupled with more right posterior activity (Engels et al., 2007; Heller & Nitschke, 1998; Nitschke, Heller, Palmieri, & Miller, 1999). Consistent with this observation, the right hemisphere is involved in vigilance and autonomic arousal (Compton et al., 2003; Heller, Nitschke, & Lindsay, 1997) and has been implicated in studies of patients with panic disorder or panic symptoms (Reiman, Raichle, Butler, Herscovitch, & Robins, 1984; Swedo et al., 1989) and in studies of non-patients in high-stress situations (Tucker, Roth, Arneson, & Buckingham, 1977).

Much of the work examining attentional bias in anxious populations has relied on measures such as the State-Trait Anxiety Inventory (STAI; Spielberger, 1968), a measure of anxiety that is highly correlated with anxious apprehension and depression (less so with anxious
arousal), indicating that the STAI is not specific to any one type of anxiety, or to anxiety at all (Nitschke, Heller, Imig, McDonald, & Miller, 2001). Thus, research relying solely on the STAI as a measure of anxiety conflates anxious apprehension and anxious arousal, in effect treating anxiety as a unitary construct. Moreover, the measure conflates anxiety and depression.

Sass et al. (2010) used ERPs to investigate the time course of attentional bias in the emotion-word Stroop task in individuals scoring high on measures of anxious apprehension or anxious arousal. Anxious apprehension and anxious arousal were associated with evidence for early detection of emotional arousal (larger N200 and P100 amplitude to emotionally arousing stimuli for anxious apprehension and anxious arousal groups, respectively), in the absence of evidence for group differences later in the trial measured by P300 and N400 amplitude. Anxious arousal women showed larger P100 amplitude than anxious arousal men for all stimuli, including neutral, perhaps reflecting generalized tonic vigilance for visual input. Taken together, these results suggest that anxious arousal participants bias attention to emotionally arousing stimuli earlier than do anxious apprehension participants. Neither group showed evidence for prolonged engagement with emotional stimuli. Furthermore, the pattern of effects for P100 differed in the anxious arousal group as a function of gender. Results support the suggestion that the conjunction of valence, arousal, and gender is critical in examining attentional bias in anxiety.

Attentional Bias to "Non-Emotional" Stimuli in Anxiety

Few studies have examined whether anxious participants also show biased processing of stimuli that vary in the difficulty of attentional processing demands but do not contain an explicit “emotional” dimension. Resolving this issue has implications for the specificity of attentional bias to emotional stimuli, the impact of anxiety on cognitive processing in general, and the validity of theories concerning how anxiety disorders develop and are maintained.
Anxious participants have been hypothesized to have fewer cognitive resources available for tasks due to a preoccupation with worry and/or vigilance for threat detection (e.g., Eysenck, 1997). Attentional control theory has recently been proposed to account for attentional deficits in tasks that involve stimuli without an explicit emotional dimension (ACT; Eysenck, et al., 2007). ACT proposes that anxiety widens attentional focus in order to detect potential dangers in the environment, thereby reducing attentional control with respect to any ongoing task. These effects are thought to be implemented in the brain by increasing the influence of stimulus-driven attentional systems associated with temporoparietal or ventral visual processing areas and decreasing the influence of goal-directed or top-down processing systems associated with brain activity in prefrontal cortical (PFC) areas (e.g., Bishop, 2007; Corbetta & Shulman, 2002; Eysenck, et al., 2007), resulting in a failure to inhibit task-irrelevant information. This proposal is consistent with a recent integrative account of brain regions involved in processing threatening information in anxiety. Specifically, state anxious individuals show increased activity in amygdala and ventral visual processing areas, in combination with decreased PFC activity while processing threatening information (Bishop, 2007). Decreased PFC activity in trait anxiety has also been associated with attention to non-emotional, distracting stimuli (Bishop, 2009), consistent with ACT’s suggestion that PFC activity is associated with a failure to inhibit distracting information (whether or not such information is emotional).

The ACT model also predicts that anxious individuals will show increased susceptibility to task-irrelevant or distracting non-emotional information when attentional or stimulus demands are high (Eysenck et al., 2007). For example, in a task in which participants were to comprehend text while ignoring distracting (task-irrelevant) speech, distraction had a deleterious effect on comprehension in the high- compared to low-anxious group only when the comprehension task
was demanding (Calvo & Eysenck, 1996). Bishop (2009) manipulated attentional demand via distracter congruence (distracter letter is same or different than target letter) and perceptual load (low load was a string of identical target consonants, high load was a string of different consonants, only one target). High trait-anxious participants were slower to identify targets in the condition in which the distracter was incongruent with the target, but only under low and not high perceptual load. This pattern of results is broadly consistent with ACT’s assertion that task-irrelevant, attentionally-demanding distracters should have a negative impact on attention, but inconsistent with ACT’s implication that a greater negative impact should have occurred under the most demanding condition (incongruent distracter, high load), suggesting that high attentional demand does not always impair performance in anxious participants.

This model of cognitive processing in anxiety is quite compatible with our longstanding hypothesis, empirically supported (e.g., Nitschke, Heller, & Miller, 2000; Engels et al., 2007), that anxious arousal (similar to state anxiety) is associated with increased activity in right temporoparietal regions and that this activity interferes with top-down processing and executive functioning. These brain regions are involved in scanning the visual field, spatial and emotional information processing, hierarchical control of physiological threat responding, and other aspects of cognitive and physical vigilance behavior. Anxious apprehension is also likely to interfere with cognitive control (see Nitschke & Heller, 2002, 2005, for further discussion), and may be associated with a decreased influence of prefrontal regions involved in goal-directed processing, particularly as processing demands increase.

The time course of processing of non-emotional stimuli in anxiety has been less well established than the time course of processing of emotional stimuli, though several ERP studies investigated questions regarding the effects of anxiety on tasks using non-emotional stimuli.
Most studies investigating DSM disorders likely reflect contributions of anxious arousal, anxious apprehension, and in some cases depression (which is highly comorbid with anxiety disorders, e.g., Joormann, Kosfelder, & Schulte, 2005; Kessler, Dupont, Berglund, & Wittchen, 1999). For example, anxious arousal accounted for more variance in symptoms of PTSD than did anxious apprehension or depression in one study (Palmieri, Heller, & Miller, unpublished data). Samples with participants who may have high and unquantified levels of anxious apprehension, anxious arousal, and anhedonic depression make it difficult to ascertain the contribution of these dimensions to attentional processing patterns.

A study using a fear-induction procedure (the presence of a Chilean rose-haired tarantula) with spider-anxious individuals examined state anxiety effects on flanker-task performance (judge whether the center arrow was congruent or incongruent with the surrounding arrows, Moser, Hajcak, & Simons, 2005). In the absence of behavioral performance differences, the fear-induction procedure was associated with small P300 relative to a control condition (flanker task performed in the absence of a tarantula) for target stimuli. These results were taken as evidence that fear/threat interferes with later, more controlled attentional allocation to task-relevant stimuli.

In a study investigating sustained attention in male veterans with PTSD, both visual and auditory versions of a continuous performance test (CPT-AX) were used (Shucard, McCabe, & Szymanksi, 2008). Participants responded to a quasi-random order of 11 different letters and were instructed to respond quickly and accurately to the letter “X” only when it followed the letter “A.” Participants with PTSD had longer P300 latency to visual “Xs” that did not follow “As,” indicating that longer stimulus evaluation was needed for target processing. Participants with PTSD also showed larger P300 amplitude to irrelevant nontargets (i.e., letters other than
X’s and A’s) than did controls, which was interpreted as an impaired ability to screen out irrelevant information at a later stage. The authors noted that, whereas much of the literature has focused on attentional anomalies in processing primarily trauma-related stimuli in PTSD, their study provided evidence for later, more controlled attentional processing difficulties for non-emotional stimuli.

In a study of OCD patients without comorbid panic disorder or depression (Di Russo, Zaccara, Ragazzoni, & Pallanti, 2000), participants were instructed to respond as quickly as possible only when a bar of a certain orientation (e.g., horizontal) appeared and not when a bar of another orientation (e.g., vertical) appeared. Both early and later ERPs were altered in OCD patients compared to controls. Specifically, N100 latency was longer for both targets and nontargets in OCD, and P300 amplitude did not differentiate targets from nontargets in OCD patients. This pattern of effects was interpreted as OCD patients showing nonspecific early processing of all stimuli, irrespective of whether it was a target and should be prioritized, and using more attentional resources on targets than necessary at a later stage. Taken together, the three ERP studies just summarized primarily show evidence for disrupted attention at later processing stages (P300), whereas only one of the reviewed studies showed evidence for earlier attentional anomalies. In the absence of distinguishing anxious apprehension, anxious arousal, and comorbid depression in these samples, it is not known which of these dimension(s) contributed to the attentional processing patterns observed.

In considering how anxious apprehension and anxious arousal may bias attentional processing of emotional vs. non-emotional stimuli, it is helpful to compare paradigms that are similar with respect to processing demands, differing in the emotional or non-emotional nature of the stimuli. Direct comparisons can then be made, in order to determine whether anxious
participants show evidence for attentional processing that is specific to emotional stimuli. In this
vein, the color- and emotion-word Stroop tasks make a promising comparison.

*Color-word Stroop task*

The color-word Stroop task, sometimes considered the “gold standard” of selective
attention tasks (MacLeod, 1992; MacLeod & Mathews, 1991), uses non-emotional words that
are presented in a variety of colors, and the individual identifies the ink color while ignoring the
color content of the word (e.g., the word “blue” printed in red ink). Attentional selection is
required, because the ink color must be attended regardless of the meaning of the word or the
response it prompts. Compared to a neutral baseline word, which has no intrinsic relationship to
color (e.g., “blank”), responses are facilitated if the word is the same as the ink color (e.g., “red”
in red ink), and responses are slowed if the word names a different ink color (e.g., “blue” in red
ink). The slowing of RT on incongruent trials is thought to result from word reading being much
more automatic than ink color naming, making it difficult to direct attention to color instead of
meaning.

Several behavioral studies investigating attentional abnormalities in anxiety have used the
color-word Stroop task. In an early study, a state manipulation of anxiety adversely affected
performance accuracy in an incongruent but not congruent condition (Hochman, 1967). Fox
(1993) compared high and low trait-anxious participants on incongruent, neutral, and threatening
words in a “separated” Stroop task (attend and respond to a central color patch and ignore the
word in the periphery) and a “traditional” Stroop task (attend to the centrally-presented word and
respond to the color of the word). This study found interference effects in high trait-anxious
participants (as measured by the STAI) when the incongruent word was presented in the
periphery. High trait-anxious participants also took longer to name the color of threatening
words than neutral words, regardless of whether the threatening word was presented centrally or in the periphery. These results were interpreted as supporting a general inability to maintain attentional focus when any distracting stimulus is presented in the periphery, rather than a specific inability to ignore threatening stimuli per se. Based on RT methods alone, it is difficult to assess whether and when attentional prioritization of emotional compared to incongruent or congruent stimuli would have occurred.

A number of studies using ERPs have investigated the time course of processing in the color-word Stroop task. Only a few of these studies have also investigated anxious participants. In the first ERP Stroop studies, Warren and Marsh (1979) and Duncan-Johnson and Kopell (1981) focused on P300 latency as an index of stimulus evaluation. Both studies found no differences in P300 latency between congruent and incongruent Stroop conditions. On the basis of these null results, the authors argued that Stroop interference occurs after stimulus evaluation, during a response selection stage. P300 amplitude tends to be larger to incongruent words than to neutral and/or congruent words (Rebai, Bernard, & Lannou, 1997) but is sometimes larger to congruent than to incongruent words (e.g., Ilan & Polich, 1999). This pattern of effects is consistent in showing that neutral words tend to elicit the smallest P300, presumably due to fewer resources needed to process words that have nothing to do with the task-relevant response (color), unlike incongruent and congruent words.

A negativity peaking between approximately 400 and 500 ms at primarily fronto-central sensors is another component commonly found in color-word Stroop studies (e.g., Liotti, Woldorff, Perez, & Mayberg, 2000; Rebai et al., 1997; Silton et al., 2010; West, 2003; West & Alain 1999, 2000). Rebai et al. (1997) investigated several ERP components in a Stroop task involving congruent and incongruent (but not neutral) conditions using 5 electrode sites (Fz, Cz,
Oz, and right and left parietal) in two conditions (reading words vs. “mental naming” of words). In the absence of earlier (P100, N200) differences, N400 amplitude was larger at Cz for incongruent stimuli than congruent stimuli in the “mental naming” condition. Larger N400 for incongruent stimuli presumably reflects semantic incongruity between the meaning and color of the word. Later studies (e.g., West, 2003; West & Alain 1999, 2000) have sometimes termed this component “N450,” although it is unclear whether N400 and N450 are functionally distinct. N450 tends to be larger for incongruent than congruent and/or neutral stimuli at fronto-central sensor locations. One can thus interpret larger N450 amplitude as an index of the need for cognitive control (e.g., Curtin & Fairchild, 2003) or in a complementary fashion, as an index of the degree of incongruity between word meaning and word color (e.g., Rebai et al., 1997).

Taken together, ERP studies investigating the color-word Stroop task generally find a lack of early ERP differences between incongruent and congruent stimuli (e.g., Warren & Marsh, 1979; Rebai et al., 1997). P300 amplitude and latency also tend not to differ between incongruent and congruent stimuli (e.g., Duncan-Johnson & Kopell, 1981; Warren & Marsh, 1979). Larger N400/N450 amplitude for incongruent than congruent and/or neutral stimuli has been the most reliable component to distinguish incongruent from congruent stimuli, with neutral stimuli being inconsistently included in investigations.

Few ERP studies have investigated the color-word Stroop task in anxious populations. Those that do have tended to focus on error-related negativity (ERN). The ERN is a frontocentrally maximal, response-locked ERP component peaking approximately 50-150 ms after response execution, with amplitude largest for error trials in tasks emphasizing accuracy (e.g., Falkenstein, Hohnsbein, Hoorman, & Blanke, 1990; Gehring, Goss, Coles, Meyer, & Donchin 1993). For example, individuals with OCD evidenced larger and prolonged ERN to
error trials during a color-word Stroop task, and ERN amplitude correlated positively with severity of OCD symptoms (Gehring, Himle, & Nisenson, 2000). These results were interpreted as support for the hypothesis that error signals are hyperactive in OCD. Hajcak, McDonald, and Simons (2003) focused on individuals scoring high on a measure of anxious apprehension (PSWQ) and also examined performance on a color-word Stroop task. Participants scoring high on the PSWQ showed enhanced ERN amplitude relative to phobic and control participants, indicating that sensitivity to error generalizes beyond OCD to anxious apprehension.

In summary, few studies have investigated the color-word Stroop task in anxiety using ERPs (let alone systematically for anxious apprehension and anxious arousal). The few ERP studies that focus on anxiety have tended to focus on error processing. Early and later stages of stimulus-related processing have not been systematically differentiated. Lack of such differentiation makes it difficult to compare results to those in the emotion-word Stroop literature. Furthermore, no ERP studies have systematically compared emotion- and color-word Stroop tasks in anxiety, in order to more carefully examine the specificity of various attentional processing stages for emotional stimuli, despite its theoretical importance.

The Experimental Problem

Although recent theorizing assumes it, the specificity of attentional bias to emotional stimuli in anxiety is unclear. So-called neutral or “non-emotional” stimuli varying in attentional processing demands have not been systematically investigated or contrasted with emotional stimuli. Clarifying this issue is critical in understanding the specificity of attention to emotional (particularly threatening) stimuli in anxiety and whether this bias generalizes to cognitively demanding stimuli without an explicit emotional dimension. Resolution of this issue has
implications for supporting and/or refining the hypothesis that preferential attention to threatening stimuli is an etiological and maintaining factor of anxiety.

The attentional bias literature has not differentiated types of attention well, typically treating attention as a monolithic construct. The present study is thus limited in the specificity with which predictions can be made in terms of a) which attentional processes should be affected and b) when. The time course of attentional phenomena is operationalized here in terms of the latency of ERP components: components < 300 ms are considered "early" and components > 300 ms are considered "late".

In order to investigate the specificity of attentional prioritization of emotional stimuli, the present project first investigated ERP results within the emotion-word Stroop task to test whether early preferential sensory processing seen previously in anxious apprehension and anxious arousal (Sass et al., 2010) is specific to anxiety, generalizes to anhedonic depression, or generalizes to comorbid anxiety and depression. Second, the present project compared ERP results from the emotion- and color-word Stroop tasks in anxious apprehension, anxious arousal, anhedonic depression, comorbid (high on measures of anxious apprehension, anxious arousal, and anhedonic depression), and control participants, in order to investigate the specificity of attentional prioritization of emotional versus non-emotional stimuli in anxiety. The comorbid group is included in order to facilitate comparisons of the present project with a literature that has largely relied on measures of trait anxiety (such as the STAI) that effectively conflate anxiety and depression and provide unknown comorbidity. The anhedonic depression group is included as a control group, in order to disambiguate potential differential patterns of processing in the anxious and comorbid groups. These were the main hypotheses:

1) Within the emotion-word Stroop task, if early preferential sensory processing of
unpleasant or emotionally arousing stimuli is specific to anxiety (reflected in P100 and/or N200 amplitude), the anhedonic depression and control groups should not show such early preferential processing. Based on inconsistency in the literature, it is unclear whether early effects will occur in the comorbid group.

2) In comparing the emotion- and color-word tasks, if early preferential sensory processing of unpleasant or emotionally arousing compared to attentionally-demanding-neutral stimuli is specific to anxiety, P100 and/or N200 amplitude will be larger for emotionally arousing than neutral stimuli in anxious participants. Conversely, attentionally-demanding-neutral stimuli (i.e., congruent and incongruent stimuli from the color-word Stroop task) may require a) equivalent or b) greater attentional resources than emotional stimuli at an early attentional stage.

3) If later preferential attentional processing of unpleasant or emotionally arousing stimuli is specific to anxiety, P300 amplitude will be larger for emotionally arousing than non-emotional attentionally-demanding stimuli in anxious participants. Conversely, attentionally-demanding-neutral stimuli (i.e., congruent and incongruent stimuli from the color-word Stroop task) may require a) equivalent or b) greater attentional resources than emotional stimuli at a later stage in processing.

In the color-word Stroop task, N400 is sometimes larger for incongruent than congruent or neutral stimuli, and N400/N450 amplitude has been suggested to be an index of the need for cognitive control. Thus, N400 may be larger for congruent and/or incongruent than emotionally arousing words if attentionally demanding neutral words require more cognitive control to process. This effect may be pronounced in anxiety. An alternative hypothesis is that neutral words may be incongruent with overall expectancies for emotional content in the emotion-word
Stroop, and for color meaning in the color-word Stroop task. Thus, N400 amplitude may be larger for neutral words in the emotion-word than color-word Stroop task if emotion is more strongly primed in than color meaning, and this effect may be particularly pronounced in anxiety.

Because N400 is a relatively automatic response to words (and semantic stimuli more broadly), it could be viewed similarly to earlier ERP components such as P100 and N200, which also index relatively automatic processing. Given that the time course of attentional phenomena (including the processes indexed) is underdeveloped in the attentional bias literature but that N400 clearly follows some early phenomena, the present study treats N400 as a "late" component.

In order to address hypotheses 2 and 3, targeted comparisons were made between the emotion- and color-word Stroop tasks. First, to address preferential processing of unpleasant over neutral stimuli, unpleasant stimuli were compared to neutral stimuli from the color-word Stroop task (congruent and incongruent words were each compared to unpleasant words, and an average of congruent and incongruent words was compared to unpleasant words). This analysis addressed the following possibilities: a) whether unpleasant stimuli were prioritized over neutral stimuli which were attentionally demanding (due to potential conflict), b) whether unpleasant stimuli and attentionally–demanding-neutral stimuli did not differ in terms of attentional prioritization, or c) whether attentionally-demanding-neutral stimuli were prioritized over unpleasant stimuli.

Second, to address preferential processing of emotionally arousing over neutral stimuli, an average of emotionally arousing (pleasant and unpleasant) stimuli was compared to neutral stimuli from the color-word Stroop task (congruent and incongruent words were each compared to emotionally arousing words, and an average of congruent and incongruent words was
compared to an average of emotionally arousing words). This analysis addressed the following possibilities: a) whether emotionally arousing stimuli more generally were prioritized over neutral stimuli which were attentionally demanding (due to potential conflict), b) whether emotionally arousing stimuli and attentionally-demanding-neutral stimuli did not differ in terms of attentional prioritization, or c) whether attentionally-demanding-neutral stimuli were prioritized over emotionally arousing stimuli.

Gender was analyzed based on well-established evidence for its importance in the neural processing of emotional stimuli and on the need to understand the greater prevalence rate of anxiety and depression disorders in women than men. Women scoring highly on measures of anxious apprehension, anxious arousal, and anhedonic depression may show pronounced preferential attention to emotional compared to non-emotional stimuli. An unusually large database was available for testing these hypotheses. The author was involved throughout graduate school from the beginning of EEG data collection, had a primary role and responsibility for EEG data collection and analysis preprocessing later in graduate school, and developed the present rationale and hypotheses. This dissertation pursued novel processing and analysis of this data set in order to address the issues discussed above.


CHAPTER 2

METHOD

Participants

Participants were 130 (68 female) undergraduates with usable emotion- and color-word Stroop data. Participants were paid volunteers (mean age = 19.0, $SD = 1.6$) recruited via group questionnaire screening sessions. Participants were classified as high comorbidity ($N = 22$, 16 female), high anxious apprehension ($N = 17$, 13 female), high anxious arousal ($N = 24$, 12 female), high anhedonic depression ($N = 24$, 7 female), or control ($N = 43$, 20 female) on the basis of responses on the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990; Molina, & Borkovec, 1994) and the Mood and Anxiety Symptom Questionnaire (MASQ; Watson, Clark, et al., 1995; Watson, Weber, et al., 1995; see Appendix A). Based on a sample of more than 1000 participants, cutoffs for group participation were formed for the PSWQ, MASQ Anxious Arousal scale, and an 8-item subset of the MASQ Anhedonic Depression scale that emphasizes depressed mood rather than low positive affect (Nitschke et al., 2001). The comorbid group scored above the 80th percentile on the PSWQ, MASQ Anxious Arousal scale (MASQAA), and a depressed-mood subscale (Nitschke et al., 2001) of the MASQ Anhedonic Depression scale (MASQAD8). The anxious apprehension group scored above the 80th percentile on the PSWQ and below the 50th percentile on the other two scales. The anxious arousal group scored above the 80th percentile on the MASQAA and below the 50th percentile on the other two scales. The anhedonic depression group scored above the 80th percentile on the MASQAD8 and below the 50th percentile on the other two scales. The control group scored below the 50th percentile on all three scales. Percentiles were derived from the group questionnaire screening sessions and were not gender-specific. The questionnaires were administered for a second time when participants individually attended the laboratory tour.
Table 1 reports participant demographics. All participants were right-handed, native speakers of English with self-reported normal color vision. Participants were given a laboratory tour, informed of the procedures of the study, and screened for claustrophobia or contraindications for MRI participation because of other procedures as part of a larger protocol.

Stimuli and Experimental Design

Participants completed two tasks, an emotion- and a color-word Stroop task. The order of presentation of the two tasks was counterbalanced across participants. Word presentation and response recording were controlled by STIM software (James Long Company, Caroga Lake, NY). The emotion-word Stroop task consisted of blocks of pleasant or unpleasant words alternating with blocks of neutral words. Several pilot studies for this project as well as published work show that a blocked design is more effective in eliciting emotion-word Stroop interference than an intermixed design (e.g., Compton et al., 2003; Dalgleish, 1995). The color-word Stroop task consisted of blocks of color-congruent or color-incongruent words alternating with blocks of neutral words. Additional neutral trials were intermixed 50:50 in congruent and incongruent blocks to prevent the development of word-reading strategies. This type of blocked design in the color-word Stroop task has been shown to effectively elicit Stroop interference (Banich et al., 2000; Milham, Banich, Claus, & Cohen, 2003). The order of presentation of blocks in the present investigation was counterbalanced for each participant. In addition to the 16 word blocks, there were four fixation blocks - one at the beginning, one at the end, and two in the middle of the session. In the fixation condition, a fixation cross was presented for 1500 ms.

Each task consisted of 256 trials in 16 blocks (four pleasant, four unpleasant, and eight neutral; or four congruent, four incongruent, and eight neutral) of 16 trials, with a variable ITI (2000 +/- 225 ms) between trial onsets. Each trial consisted of one word presented in 1 of 4 ink
colors (red, yellow, green, blue) on a black background, with each color occurring equally often with each word type (pleasant, neutral, unpleasant; or congruent, incongruent, neutral). The 256 word stimuli included in the emotion-word Stroop task were selected from the Affective Norms for English Words set (Bradley & Lang, 1999). Sixty-four were pleasant (e.g., birthday, ecstasy, laughter), 64 were unpleasant (e.g., suicide, war, victim), and two sets of 64 were neutral (e.g., hydrant, moment, carpet). The words were carefully selected on the basis of established norms for valence, arousal, frequency of usage in the English language (Bradley & Lang 1999), and number of letters. The color-word task consisted of congruent trials in which the word named the ink color in which it was printed (e.g., the word ‘‘RED’’ printed in red ink), incongruent trials in which the word named a color incongruent with the ink color in which it was printed (e.g., ‘‘GREEN’’ in red ink), and neutral trials in which the word was unrelated to color (e.g., ‘‘LOT’’ in red ink). Neutral words were matched with color words for word frequency and length. Words ranged from three to eight letters and were centered on a black background.

Words were presented in capital letters using Tahoma 72-point font at a distance of 1.35 m from the participant’s eyes, for a vertical span of 1.5 degrees and a horizontal span of 2.5 to 9.3 degrees for the emotion-word Stroop, and 3.2 to 8.7 degrees for the color-word Stroop. Participants responded with their index and middle fingers using a four-button response box (James Long Company) under each hand, with the emotion- and color-word tasks using the same mapping of color to button for a given subject. Given that the number of neutral trials was double that for pleasant or unpleasant words within the emotion-word Stroop task, a subsampling of 128 neutral trials was undertaken. Thus, the full set of 128 or a subset of 64 neutral trials could be used in analyses. ERP analyses subsequently reported are based on the subset of 64 neutral trials. Critical tests of hypotheses did not differ when using the full set of 128 or the
subset of 64. Given differing trial numbers in the emotion- and color-word Stroop tasks, subsampled averages were used in analyses reported in the Results section. Specifically, pleasant and unpleasant trials were subsampled to \( N=32 \) in order to equate them in number with available congruent and incongruent trials. Critical tests of hypotheses did not differ when using the full set of 64 or the subset of 32.

The emotion- and color-word Stroop tasks involved a blocked design, which means that primarily tonic rather than phasic attention effects were manipulated as a function of word type. Furthermore, blocking was done differently in the two tasks. In the emotion-word Stroop task, pleasant and unpleasant blocks were not interspersed with neutral trials. In the color-word Stroop task, during congruent and incongruent blocks half the trials were neutral, as well as having neutral-only blocks. These considerations will be kept in mind when interpreting results.

A further consideration in comparing groups on the emotion- and color-word Stroop tasks is whether groups actually differ in performance on these tasks. Loren and Jean Chapman (e.g., Chapman & Chapman, 1978, 2001) have discussed the pitfalls of drawing conclusions about whether a particular group shows a "differential deficit" on Task A vs. Task B compared to another group, unless Task A and Task B have been matched psychometrically on item difficulty and true score variance (the product of the reliability of the test and the observed score variance), because not matching on true score variance can artifactually indicate differences in performance between the two tasks when none actually exists.

In the present study, within each of the emotion- and color-word tasks, the 5 groups performed equally on both accuracy and RT measures (i.e., Group did not interact with either accuracy or RT within either the emotion- or color-word tasks, \( ps > .1 \)). A separate repeated-measures ANOVA for accuracy and RT was conducted, including 7 levels (pure congruent, pure
incongruent, neutral congruent, neutral incongruent, pleasant, neutral, and unpleasant). These ANOVAs revealed that none of the condition levels interacted with Group (\(p > .1\)) for either accuracy or RT. Per Chapman and Chapman (1978, 2001), although group behavioral differences in processing emotional or non-emotional stimuli did not emerge, one cannot conclude that groups actually would not differ if the tasks had been psychometrically matched. Any ERP differences between the emotion- and color-word Stroop task evidenced by a particular group relative to another group in the present study therefore cannot be considered an unambiguous "differential deficit," since tasks were not psychometrically matched. Any Group x Task interactions that emerge will be interpreted with this constraint.

Electrophysiological Recordings

Participants were seated in a comfortable chair in a quiet room that was adjacent to a room where the experimenter controlled stimulus presentation and EEG data collection. The participant room was connected to the experimenter room by intercom. EEG was recorded with a custom-designed Falk Minow 64-channel cap with Ag/AgCl electrodes spaced equidistantly. The left mastoid was the online reference for all EEG and electrooculogram (EOG) sites. Electrodes placed above and below each eye and near the outer canthus of each eye recorded vertical and horizontal EOG for off-line eye-movement artifact correction of EEG. Electrode impedances were maintained below 20 Kohms. Amplifier bandpass was .1 to 100 Hz, and data were digitized at 250 Hz. Electrode positions were recorded using a Zebris ELPOS digitizer (Zebris Medizintechnik, Tübingen, Germany).

Data Reduction

Via Brain Electrical Source Analysis (BESA 5.1) software, muscle, movement, and miscellaneous artifacts were removed manually, and eye-blink artifact was removed (Berg &
Scherg, 1994). If a particular channel was off-scale for many trials (approximately 10%), all trials for that channel were removed from analyses; otherwise epochs over which a given channel was off-scale were discarded (across all channels). Individual participant data with more than 5% of channels discarded due to artifact were not included in analyses ($N = 4$). Trials accurately responded to were averaged for each condition. ERP trials were rejected if reaction times were $<350$ ms or $>1400$ ms. The electrode configuration was then transformed to BESA’s standard 81-channel virtual montage using spherical spline interpolation (Perrin, Pernier, Bertrand, & Echallier, 1989), reflecting the 10-10 system. An average reference was computed for each time point as the mean voltage over the 81 standard virtual scalp electrodes. Data were exported from BESA and each channel baseline-adjusted by subtracting the average amplitude for the 200 ms before stimulus onset. Waveform averages were smoothed using a 101-weight, .1-20 Hz digital filter for P100 and N200 components and a 101-weight, .1-8 Hz digital filter for P300 and N400 (Cook & Miller, 1992; Nitschke, Miller, & Cook, 1998). To avoid identification of spurious peaks, a combination peak/area measure was used. Voltage 48 ms around the point estimate of the peak was averaged for P100 and N200, and voltage 96 ms around the peak was averaged for P300 and N400. The difference in time averaged around the peak for early ($<300$ ms) and late ($>300$ ms) components was associated with faster versus slower duration of the components. The latency associated with the peak was also recorded. All component scores were obtained for each of the 81 electrodes. Participants who displayed amplitude values less than or greater than 3 standard deviations from the mean for a particular component at more than two electrode sites were excluded from analyses including that component ($N = 8$).$^4$

Four ERP components were scored: P100 (88-128 ms), N200 (160-240 ms), P300 (300-500 ms in color-word and 448-580 ms in emotion-word Stroop), and N400 (448-580 ms). The
window for P300 peak amplitude is typically set to 300-600 ms in the color-word Stroop task and in many other oddball paradigms (e.g., Duncan-Johnson & Kopell, 1981; Ilan & Polich, 1999, 2001). However, mean P300 peak latency has been closer to 300 ms than 600 ms in such studies (Ilan & Polich, 1999, 2001). Examination of individual participant data indicated that although some subjects displayed two positive peaks during this window, almost everyone displayed a first peak which occurred before 500 ms and was larger than the second peak.

Examination of individual participants’ emotion-word Stroop waveforms indicated that many participants displayed only one peak after 450 ms, which was larger in magnitude than those participants who displayed a second peak closer to 300 ms. These observations are consistent with research using an emotion-word Stroop task, which reported a mean P300 latency close to 500 ms (e.g., Thomas, Johnstone, & Gonsalvez, 2007). Thus, the different P300 windows for the color- and emotion-word Stroop were different but are rooted in past literature as well as present data.

For P100 and N200, sites for analysis were chosen based on examination of current source density (CSD) estimates across conditions and across groups. Current source density is a transformation of the EEG to its second spatial derivative, essentially a spatial high-pass filter that reduces the spread of focal brain activity on the scalp surface and enhances the contribution of the nearby cortical surface to the recorded electrode signal (Hoechstetter et al., 2004; Nunez et al., 1999). Sites where CSD activity was maximal for P100 (P7, P8, PO7, PO8, O1, O2) and N200 (P7, P8, P9, P10, PO7, PO8, PO9, PO10) were chosen. Sites for P300 (P1, P2, P3, P4) and N400 (FC1, FC2, FC3, FC4) were chosen by integrating previous literature (e.g., Schirmer, Kotz, & Friederici, 2005) with inspection of present grand-average waveforms where effects were maximal (see Figures 1 and 2).
CHAPTER 3

RESULTS

Emotion-word Stroop Behavioral Performance

RT was analyzed for correct responses occurring between 350 and 1400 ms ($M = 665 \text{ ms}, SD = 98 \text{ ms}$). Performance accuracy was high (mean error rate = 3.4 %, $SD = 2.8$). A Group (comorbid, anxious apprehension, anxious arousal, anhedonic depression, control) x Gender (female, male) x Emotion (pleasant, neutral, unpleasant) MANOVA was conducted exploring linear (valence: comparing pleasant with unpleasant) and quadratic (arousal: comparing pleasant and unpleasant with neutral) orthogonal univariate trends on the emotion factor. $P$-values reflect the Huynh-Feldt correction for sphericity where appropriate. An alpha level of .05 was used. No main effects or interactions were significant for emotion-word Stroop RT.

Emotion-word Stroop: Early Visual Sensory Processing

A Group (comorbid, anxious apprehension, anxious arousal, anhedonic depression, control) x Gender (female, male) x Emotion (pleasant, neutral, unpleasant) x Hemisphere (left, right) MANOVA was conducted separately for P100, N200, P300, and N400 amplitude and P300 latency (see Figure 1 for grand-average waveforms for representative channels).

P100. P100 amplitude was larger over the right than left hemisphere, $F (1, 120) = 31.20, p < .001$, and larger for pleasant and unpleasant than neutral words, quadratic Emotion $F (1, 120) = 30.45, p < .001$. The Hemisphere main effect was qualified by a Group x Gender x Hemisphere interaction, $F (4, 120) = 2.46, p = .049$. This effect was explored with Gender x Hemisphere ANOVAs conducted separately for each group. A Gender x Hemisphere interaction emerged only in the anxious apprehension group, $F (1, 15) = 5.49, p = .033$, followed up
separately for each gender. Anxious apprehension men but not women showed larger P100 amplitude over right than left hemisphere.

**N200.** N200 amplitude was larger in women, \( F(1, 120) = 6.17, p = .014 \), larger over left than right hemisphere, \( F(1, 120) = 6.07, p = .015 \), and larger for emotionally arousing stimuli, quadratic Emotion \( F(1, 120) = 34.39, p < .001 \). A Group x linear Emotion interaction, \( F(1, 120) = 4.00, p = .004 \), and a Gender x linear Emotion interaction, \( F(1, 120) = 5.44, p = .021 \), emerged. Separate Emotion ANOVAs exploring linear and quadratic effects in light of hypothesis 1 were conducted for each group to follow up the Group x Emotion interaction (see Figure 3). The comorbid, anxious arousal, and control groups did not show any emotion effects. The anxious apprehension group showed larger N200 amplitude for emotionally arousing than neutral stimuli, quadratic \( F(1, 16) = 13.96, p = .002 \). The anhedonic depression group showed larger N200 amplitude for unpleasant than pleasant words, linear Emotion, \( F(1, 23) = 6.99, p = .015 \), and larger N200 amplitude for emotionally arousing than neutral stimuli, quadratic, \( F(1, 23) = 4.37, p = .048 \). Following up the Gender x linear Emotion interaction, women showed a trend for larger N200 amplitude for unpleasant than pleasant stimuli, \( F(1, 67) = 3.76, p = .057 \). Consistent with the main effect, N200 amplitude was larger for emotionally arousing than neutral stimuli in both genders (\( ps < .001 \)).

*Emotion-word Stroop: Later Processing*

**P300.** In the absence of main effects, only a Gender x quadratic Emotion x Hemisphere interaction emerged, \( F(1, 120) = 6.82, p = .010 \). Emotion x Hemisphere ANOVAs were conducted separately for each gender. Men showed a quadratic Emotion x Hemisphere interaction, \( F(1, 61) = 4.43, p = .039 \), followed up separately for each hemisphere. P300
amplitude was larger for emotionally arousing than neutral stimuli in the left hemisphere only, $F(1, 61) = 5.14, p = .027$.

**P300 latency.** In the absence of main effects, a Group x quadratic Emotion interaction, $F(4, 120) = 4.32, p = .003$, and a Gender x quadratic Emotion x Hemisphere interaction, $F(1, 120) = 4.95, p = .028$, emerged. The Group x quadratic Emotion interaction was followed up with separate Emotion ANOVAs for each group (see Figure 3). P300 latency was shorter for emotionally arousing than neutral stimuli in the anxious arousal, $F(1, 23) = 5.37, p = .030$, and anhedonic depression groups, $F(1, 23) = 6.93, p = .015$. There were no emotion effects in the comorbid, anxious apprehension, or control groups. Following up the Gender x Emotion x Hemisphere interaction, Emotion x Hemisphere ANOVAs were conducted separately for each gender. In the absence of a main effect of emotion or hemisphere in either gender, only men showed a quadratic Emotion x Hemisphere interaction, $F(1, 61) = 5.04, p = .028$. P300 latency was shorter for emotionally arousing than neutral stimuli in the left, $F(1, 61) = 7.13, p = .010$, but not right hemisphere.

**N400.** N400 amplitude was larger for emotionally arousing than neutral stimuli, $F(1, 120) = 8.13, p = .005$, and was larger over left than right hemisphere, $F(1, 120) = 9.92, p = .002$. No other main effects or interactions were significant.

*Emotion Vs. Color-word Stroop Behavioral Performance*

RT was analyzed for correct responses occurring between 350 and 1400 ms for the color-word Stroop task. The mean response was 799 ms ($SD = 127$ ms), and performance accuracy was high (mean error rate was 3.5%, $SD = 2.7$). Color-word RT was compared to emotion-word RT reported above, via a Condition factor created by pooling pleasant and congruent RT and pooling unpleasant and incongruent RT. A Group (comorbid, anxious apprehension, anxious arousal,
anhedonic depression, control) x Gender (female, male) x Task (emotion-word, color-word), x Condition MANOVA was conducted. An alpha level of .05 was used. RT was longer in the color- than emotion-word Stroop task, $F(1, 120) = 43.27, p < .001$. A main effect of condition, $F(1, 120) = 194.84, p < .001$, was qualified by a Gender x Condition interaction, $F(1, 120) = 4.21, p = .042$. Main effects and interactions with the “condition” factor were not fully interpretable with respect to critical task comparisons, because the pooling done to create this factor. Targeted analyses dissected the “condition” factor and were conducted separately for each gender. Specifically, 1) unpleasant RT was compared separately to congruent RT, incongruent RT, and an average of congruent and incongruent RT. 2) An average of emotionally arousing RT (pleasant and unpleasant) was compared separately to congruent, incongruent, and an average of congruent and incongruent RT. In the first set of contrasts, a main effect of task emerged in each contrast, with longer RT in the given CW condition than the unpleasant condition ($ps < .001$). A Gender x Task interaction emerged only in the comparison of unpleasant with incongruent stimuli, $F(1, 128) = 5.08, p = .026$. Separate ANOVAs were conducted for each condition and each gender. Men were faster than women in the incongruent and not unpleasant condition, $F(1, 128) = 6.59, p = .011$. RT was slower for incongruent than unpleasant words in men, $F(1, 61) = 77.78, p < .001$, and women, $F(1, 67) = 123.41, p < .001$. In the second set of contrasts, a main effect of task emerged in each contrast, with longer RT in the given CW condition than the average of the emotionally arousing stimuli ($ps < .001$). A Gender x Task interaction emerged only in the comparison of emotionally arousing with incongruent stimuli, $F(1, 128) = 5.17, p = .025$. Separate ANOVAs were conducted for each condition and each gender. Men were faster than women in the incongruent and not emotionally
arousing condition, $F(1, 128) = 6.59, p = .011$. RT was slower for incongruent than emotionally arousing words in men, $F(1, 61) = 82.55, p < .001$, and women, $F(1, 67) = 141.51, p < .001$.

*Emotion Vs. Color-word Stroop: Early Visual Sensory Processing*

A Group (comorbid, anxious apprehension, anxious arousal, anhedonic depression, control) x Gender (female, male) x Task (emotion-word, color-word), x Condition (pleasant and congruent, unpleasant and incongruent) x Hemisphere (left, right) MANOVA was conducted separately for P100, N200, P300, and N400 amplitude and P300 latency (see Figures 1 and 2 for grand-average waveforms for representative channels in both tasks). As mentioned above, main effects and interactions with the “condition” factor were not fully interpretable with respect to critical task comparisons. When condition effects emerged, targeted contrasts were pursued in order to compare the emotion with the color-word Stroop tasks, in line with critical hypotheses. Specifically, 1) unpleasant stimuli were compared separately to congruent, incongruent, and an average of congruent and incongruent stimuli. 2) An average of emotionally arousing stimuli (pleasant and unpleasant) was compared separately to congruent, incongruent, and an average of congruent and incongruent stimuli, following hypotheses 2 and 3.

**P100.** P100 was larger over the right than left hemisphere, $F(1, 120) = 32.01, p < .001$. No other effects emerged.

**N200.** N200 amplitude was larger for women, $F(1, 120) = 9.26, p = .003$, and larger over the left than right hemisphere, $F(1, 120) = 6.62, p = .011$. A Group x Condition interaction, $^4 F(4, 120) = 2.50, p = .046$, was qualified by a Group x Gender x Condition interaction, $F(4, 120) = 2.78, p = .030$. The latter effect also qualified the gender main effect. Targeted contrasts interrogated the interaction of group, gender, and condition. These contrasts followed the hypothesis that emotional (either unpleasant specifically or emotionally arousing
more generally) stimuli would be prioritized over neutral stimuli if there is a “bias” for emotional stimuli at this early time point (hypothesis 2). Separate Gender x Condition ANOVAs were conducted for each group, comparing a) unpleasant to congruent stimuli, b) unpleasant to incongruent stimuli, and c) unpleasant to the average of congruent and incongruent stimuli. When comparing unpleasant to congruent stimuli, N200 amplitude was larger for congruent than unpleasant stimuli in the anxious apprehension, $F(1, 15) = 6.83, p = .020$, and control groups, $F(1, 41) = 18.03, p < .001$. No main effects or interactions emerged for the other groups. When comparing unpleasant to incongruent stimuli, N200 amplitude was larger for incongruent than unpleasant stimuli in the anxious apprehension, $F(1, 15) = 6.61, p = .021$, and control groups, $F(1, 41) = 27.40, p < .001$. No main effects or interactions emerged for the other groups. Finally, in a comparison of unpleasant to the average of congruent and incongruent stimuli, N200 amplitude was larger for congruent and incongruent than unpleasant stimuli in the anxious apprehension, $F(1, 15) = 6.61, p = .021$, and control groups, $F(1, 41) = 26.69, p < .001$. No main effects or interactions emerged for the comorbid, anxious arousal, and anhedonic depression groups.

The second set of contrasts (following hypothesis 2) involved separate Gender x Condition ANOVAs conducted for each group, comparing a) emotionally arousing to congruent stimuli, b) emotionally arousing to incongruent stimuli, and c) emotionally arousing to the average of congruent and incongruent stimuli. When comparing emotionally arousing and congruent stimuli, N200 amplitude was larger for congruent than emotionally arousing stimuli in the anxious arousal, $F(1, 22) = 5.84, p = .024$, and control groups, $F(1, 41) = 14.21, p = .001$. No main effects or interactions emerged for the other groups. When comparing emotionally arousing and incongruent stimuli, the anxious arousal group showed a Gender x Condition
interaction, $F(1, 22) = 6.38, p = .019$ (see Figure 4). Anxious arousal men showed larger N200 amplitude for incongruent than emotionally arousing stimuli, $F(1, 11) = 8.69, p = .013$. Anxious arousal women did not differentiate incongruent from emotionally arousing stimuli, suggesting equivalent attention to stimuli in these two task contexts. The control group showed a main effect of condition, $F(1, 41) = 6.66, p = .014$, and a Gender x Condition interaction, $F(1, 41) = 4.69, p = .036$ (see Figure 4). Control men did not differentiate incongruent from emotionally arousing stimuli, suggesting equivalent attention to stimuli in these two task contexts. Control women showed larger N200 amplitude for incongruent than emotionally arousing stimuli, Condition $F(1, 19) = 6.74, p = .018$. No main effects or interactions emerged for the comorbid, anxious apprehension, and anhedonic depression groups. When comparing emotionally arousing to the average of congruent and incongruent stimuli, N200 amplitude was larger for neutral than emotionally arousing stimuli in the anxious arousal, $F(1, 22) = 18.13, p = .011$, and control groups, $F(1, 41) = 21.17, p < .001$. No main effects or interactions emerged for the other groups.

**Emotion Compared to Color-word Stroop: Later Processing**

**P300.** P300 amplitude was larger in the color- than emotion-word Stroop task, $F(1, 120) = 33.18, p < .001$. This main effect of task was qualified by a Task x Hemisphere effect, $F(1, 120) = 31.58, p < .001$. Task ANOVAs were conducted for each hemisphere. P300 amplitude was larger in the color- than emotion-word Stroop in the right but not left hemisphere, $F(1, 120) = 79.31, p < .001$. A Group x Condition x Hemisphere effect, $F(4, 120) = 2.55, p = .043$, was qualified by a Group x Gender x Condition x Hemisphere effect, $F(4, 120) = 5.03, p = .001$. Targeted contrasts followed the hypothesis that emotional (either unpleasant specifically or emotionally arousing more generally) stimuli would be prioritized over neutral stimuli if there is
a “bias” for emotional stimuli at this later time point (hypothesis 3). Specifically, the first set of contrasts involved separate Gender x Condition x Hemisphere ANOVAs conducted for each group, comparing a) unpleasant to congruent stimuli, b) unpleasant to incongruent stimuli, and c) unpleasant to the average of congruent and incongruent stimuli.

When comparing unpleasant to congruent stimuli, a Condition x Hemisphere interaction emerged for the anxious arousal, $F(1, 22) = 5.81, p = .025$, and control groups, $F(1, 41) = 4.09, p = .050$. P300 amplitude was larger in the right hemisphere for congruent than unpleasant stimuli in the anxious arousal, $F(1, 22) = 5.52, p = .028$, and control groups, $F(1, 41) = 13.41, p = .001$. No effects emerged for the other groups. When comparing unpleasant to incongruent stimuli, P300 amplitude was larger over right than left hemisphere in the comorbid group, $F(1, 19) = 6.11, p = .023$, qualified by a Gender x Hemisphere interaction, $F(1, 19) = 7.99, p = .011$. P300 amplitude was larger over right than left hemisphere in comorbid men, $F(1, 5) = 6.48, p = .050$, but not in comorbid women. A Condition x Hemisphere interaction emerged for the anxious arousal, $F(1, 22) = 6.34, p = .020$, and control groups, $F(1, 41) = 8.90, p = .005$. P300 amplitude was larger over right than left hemisphere in the anxious arousal group for incongruent words, $F(1, 22) = 6.66, p = .017$. P300 amplitude was larger over right hemisphere for incongruent than unpleasant stimuli in the control group, $F(1, 41) = 5.85, p = .020$. No effects emerged for the anxious apprehension or anhedonic depression group. Finally, when comparing unpleasant to the average of congruent and incongruent stimuli, a Condition x Hemisphere interaction emerged for the anxious arousal, $F(1, 22) = 7.52, p = .012$, and control groups, $F(1, 41) = 6.99, p = .012$. P300 amplitude was larger over right than left hemisphere in the anxious arousal group for incongruent and congruent words, $F(1, 22) = 7.83, p = .010$. P300 amplitude was larger over right hemisphere for congruent and incongruent stimuli than unpleasant stimuli.
in the control group, \( F(1, 41) = 10.99, p = .002 \). No effects emerged for the comorbid, anxious apprehension, and anhedonic depression groups.

The second set of contrasts following hypothesis 3 involved separate Gender x Condition x Hemisphere ANOVAs conducted for each group, comparing a) emotionally arousing to congruent stimuli, b) emotionally arousing to incongruent stimuli, and c) emotionally arousing to the average of congruent and incongruent stimuli. When comparing emotionally arousing to congruent stimuli, the anxious apprehension, \( F(1, 15) = 4.72, p = .046 \), anxious arousal, \( F(1, 22) = 8.45, p = .008 \), and anhedonic depression groups, \( F(1, 22) = 5.24, p = .032 \), showed a Condition x Hemisphere interaction. Separate Hemisphere ANOVAs were done for each condition, and separate Condition ANOVAs were done for each hemisphere. There was a trend for P300 amplitude to be larger in the right than left hemisphere for neutral than emotionally arousing stimuli in the anxious apprehension group, \( F(1, 15) = 4.24, p = .056 \). P300 amplitude was larger in right than left hemisphere for neutral than emotionally arousing stimuli in the anxious arousal group, \( F(1, 23) = 5.71, p = .025 \). No effects emerged in this dissection of the interaction in the comorbid or anhedonic depression group. A main effect of task, \( F(1, 41) = 12.89, p = .011 \), and a Gender x Hemisphere interaction, \( F(1, 41) = 4.61, p = .038 \), emerged for the control group. P300 amplitude was larger over right than left hemisphere in men only, \( F(1, 22) = 7.13, p = .014 \).

When comparing emotionally arousing to incongruent stimuli, the comorbid group showed a Gender x Condition interaction, \( F(1, 19) = 4.85, p = .040 \), a Gender x Hemisphere interaction, \( F(1, 19) = 7.48, p = .013 \), and a Condition x Hemisphere interaction, \( F(1, 19) = 7.72, p = .012 \). All three of these interactions were qualified by a Gender x Condition x Hemisphere interaction, \( F(1, 19) = 4.50, p = .047 \) (see Figure 4). Separate Condition x
Hemisphere ANOVAs were conducted for each gender. Comorbid men showed a Hemisphere effect, $F (1, 5) = 8.13, p = .036$, and a Condition x Hemisphere interaction, $F (1, 5) = 6.60, p = .050$, followed up with separate Hemisphere ANOVAs for each condition, and separate Condition ANOVAs for each hemisphere. P300 amplitude was larger in the right than left hemisphere in the incongruent condition only in comorbid men, $F (1, 5) = 12.20, p = .017$. P300 amplitude was larger for the incongruent than emotionally arousing stimuli in comorbid women, $F (1, 14 ) = 9.58, p = .008$. A Condition x Hemisphere interaction emerged for the anxious arousal, $F (1, 22) = 7.95, p = .010$, and control groups, $F (1, 41) = 8.77, p = .005$, followed up with separate Hemisphere ANOVAs for each condition, and separate Condition ANOVAs for each hemisphere. P300 amplitude was larger over left than right hemisphere in the incongruent condition in the anxious arousal group, $F (1, 23) = 6.66, p = .017$. P300 amplitude was larger in the right hemisphere for incongruent than emotionally arousing stimuli in the control group, $F (1, 42) = .6.36, p = .016$. No effects emerged for the anxious apprehension and anhedonic depression group.

Finally, when comparing emotionally arousing to the average of congruent and incongruent stimuli, a main effect of condition, $F (1, 20) = 5.96, p = .024$, was qualified by a Gender x Condition interaction in the comorbid group. Only comorbid women showed larger P300 amplitude for congruent and incongruent than emotionally arousing stimuli. Comorbid men did not differentiate congruent and incongruent from emotionally arousing stimuli, suggesting equivalent attention to stimuli in these two task contexts. A Condition x Hemisphere effect, $F (1, 15) = 5.39, p = .035$, emerged for the anxious apprehension group in the absence of a main effect of condition or hemisphere. P300 amplitude was larger for the color- than emotion-word Stroop over right hemisphere only in this group, $F (1, 15) = 6.86, p = .019$. A main effect
of condition, $F(1, 22) = 6.49, p = .018$, was qualified by a Condition x Hemisphere effect in the anxious arousal group, $F(1, 22) = 12.42, p = .002$. P300 amplitude was larger for the color-than emotion-word Stroop over right hemisphere only, $F(1, 22) = 13.28, p = .001$. The control group showed both a main effect of condition, $F(1, 41) = 28.47, p <.001$, and a Condition x Hemisphere effect, $F(1, 41) = 12.18, p = .001$. P300 amplitude was larger for the color-than emotion-word Stroop over left, $F(1, 41) = 10.66, p = .002$, and right hemisphere, $F(1, 41) = 49.86, p <.001$. No effects emerged for the anhedonic depression group.

**N400.** N400 amplitude was larger over left than right hemisphere, $F(1, 120) = 31.09, p <.001$. No other effects emerged.
CHAPTER 4
DISCUSSION

Although recent theorizing assumes it, the specificity of attentional bias to emotional stimuli in anxiety is unclear. So-called neutral or “non-emotional” stimuli varying in attentional processing demands have not been systematically investigated or contrasted with emotional stimuli. Clarifying this issue is critical in understanding the specificity of preferential attention to emotional (particularly threatening) stimuli in anxiety and has implications for supporting and/or refining the hypothesis that preferential attention to threatening stimuli is an etiological and maintaining factor of anxiety. The present study focused on two sets of analyses. First, anhedonic depression and comorbid groups were investigated as control groups within the emotion-word Stroop task to see whether attentional bias (early sensory attentional bias in particular) was specific to anxiety. Second, the emotion- and color-word Stroop tasks were directly compared in order to investigate whether preferential processing of emotional over neutral stimuli relies on the nature of the neutral stimulus, specifically whether neutral stimuli are more attentionally demanding.

*Emotion-word Stroop Findings*

The first hypothesis, that preferential early sensory attention would be specific to anxiety, was not supported. The present findings extend Sass et al. (2010) by finding preferential processing of unpleasant than pleasant stimuli in anhedonic depression, consistent with the hypothesis that depression should be associated with mood-congruent biases in attention (Beck, 1976), and not only in anxiety. The anhedonic depression group also showed evidence for preferential processing of emotionally arousing over neutral stimuli. Thus, early sensory preferential processing of emotional stimuli was not specific to anxiety in the present study.
Whereas anxiety has been strongly associated with an attentional bias to threatening or unpleasant stimuli (Fox et al., 2002; McNally, 1998; Williams et al., 1996), evidence for such bias in depression has been mixed (for reviews see Gotlib & Joormann, in press; Mineka, Watson, & Clark, 1998; Mogg & Bradley, 2005). The present data showing early bias in depression are consistent with previous findings. Specifically, when attentional bias is found in depression, several patterns emerge. First, unpleasant stimuli are sometimes prioritized (Bradley, Mogg, & Lee, 1997; Gotlib & Cane, 1987) consistent with mood-congruent processing as predicted by Beck (1976). Second, evidence for insufficient attention to pleasant stimuli is sometimes found (Gilboa & Gotlib, 1997; Gotlib, McLachlan, & Katz, 1988; McCabe & Gotlib, 1995; McCabe, Gotlib, & Martin, 2000), suggesting that biases can result in an underprioritization of information inconsistent with mood rather than a prioritization of information consistent with mood. Finally, a lack of differentiation between pleasant and unpleasant stimuli is sometimes found (e.g., McCabe & Gotlib, 1995), suggesting an evenhanded attentional strategy and inconsistent with a mood-congruent bias. Given the inconsistent inclusion of pleasant stimuli in this literature (e.g., Mathews, Ridgeway, & Williamson, 1997) and a general lack of consideration for whether pleasant and unpleasantly valenced emotional stimuli are matched on emotional arousal, it is possible that an emotional arousal confound contributed to variance in past findings.

In the present study, anxious apprehension and anhedonic depression were associated with an early sensory preferential bias for emotional stimuli, whereas comorbidity was not. Anxiety and depression are frequently comorbid (Brown, Campbell, Lehman, Grisham, & Mancill, 2001; Joormann et al., 2005; Kessler et al., 1999; Sanderson, DiNardo, Rapee, & Barlow, 1990). With few exceptions, studies have not carefully screened anxious participants for
high levels of depression and vice versa. Thus, given symptom overlap in previous studies, the present study adds to the literature by suggesting that attentional bias occurs in individuals endorsing “pure” depression, without co-occurring anxiety symptoms.

Anxious arousal and anhedonic depression were associated with faster evaluation of emotionally arousing than neutral stimuli at a later time point (P300 latency), in the absence of such effects in the comorbid, anxious apprehension, or control groups. Faster evaluation of emotionally arousing stimuli in the anxious arousal and anhedonic depression groups suggests that emotional arousal facilitates rather than hinders emotional stimulus processing at a later time point, contrary to suggestions that emotional content may lead to greater elaborative processing (e.g., Fox et al., 2002; Mogg and Bradley, 2005). That the anhedonic depression group did not show slower evaluation (as reflected in P300 latency) of unpleasant than pleasant information suggests that unpleasant stimuli are not uniformly preferentially processed in depression at all attentional processing stages.

Separate analyses (not reported here) were conducted on individuals who met criteria for a DSM-IV-TR diagnosis of an anxiety disorder (without depression) or a depression diagnosis (without anxiety). The anxious but not the depressed group showed preferential early sensory processing of unpleasant compared to pleasant stimuli and emotionally arousing compared to neutral stimuli in the absence of later effects. Depressed women showed later preferential processing of emotionally arousing stimuli. The comorbid group showed no preferential processing effects. These findings are mentioned here to illustrate that dimensional and categorical classification of anxiety and depression result in different but related patterns of processing. Thus, how anxiety and depression are defined likely further contributes to mixed
findings of bias in the anxiety and depression literature and remains an important variable to be systematically studied in future research.

*Emotion- and Color-Word Stroop Comparison*

The second set of analyses in the present study directly compared emotion- and color-word Stroop tasks in order to investigate whether preferential processing of emotional stimuli seen in the emotion-word Stroop context, relying on comparisons with neutral stimuli with no inherent conflict, would generalize to a comparison with non-emotional stimuli from the color-word Stroop context, which are presumably more difficult to process due to inherent potential conflict between word meaning and word color (congruent and incongruent stimuli). There was no evidence for either early or later preferential processing of emotional over congruent and incongruent stimuli in anxious groups. Direct comparison of the emotion- and color-word Stroop tasks in anxiety and depression suggests that the nature of neutral stimuli used in comparisons with emotional stimuli matters. Present N200 and P300 evidence for preferential attention to emotional over neutral stimuli occurred only within the emotion-word Stroop task, where neutral stimuli did not have conflicting color and meaning dimensions. Conversely, when neutral stimuli had potentially competing word color and meaning dimensions, preferential processing of emotional stimuli in anxiety and depression was not found. Indeed, evidence for preferential processing of neutral color-word Stroop stimuli over emotionally arousing stimuli was found. A lack of preferential processing of either neutral or emotionally arousing stimuli was also found. No evidence for preferential processing of emotional stimuli over “neutral” stimuli from the color-word Stroop task was apparent.

In future research, neutral stimuli that are easier or harder to process could be contrasted with emotional stimuli with varying attentional demands, in order to better evaluate the
conditions under which early or later attention is truly preferential for emotional stimuli in anxiety. The present data challenge the generality of preferential attention to emotional information in anxiety and suggest that deployment of attention to emotional vs. non-emotional information is constrained by the processing demands associated with emotional and non-emotional stimuli.

**Intervention Implications**

Present data have several intervention implications. First, these data suggest that investigating unpleasant to the exclusion of pleasant stimuli is misleading. Within the emotion-word Stroop task, both anxiety groups showed evidence for preferential processing of emotionally arousing stimuli in general, rather than of unpleasant alone. The anhedonic depression group showed evidence for preferential processing of unpleasant over pleasant and also of unpleasant and pleasant over neutral stimuli. Interventions for anxiety and depression may benefit from a focus on emotional arousal rather than on unpleasant valence alone.

Anxiety disorders are thought to be associated with specific fear structures (Foa & Kozak, 1986; Lang, 1977, 1979) that become activated when elements of the fear structure are encountered. Furthermore, the fear structure may enhance resource allocation and attentional processing of stimuli represented in the structure (Foa, Feske, Murdock, Kozak, & McCarthy, 1991). If the fear structure contains information associated primarily with high levels of emotional arousal (both pleasant and unpleasant), therapists conducting exposure therapy with anxiety clients could highlight the role of emotional arousal in contributing to fear experiences. For example, a client with panic disorder with agoraphobia and high levels of anxious arousal, who has learned to fear interoceptive cues, could be exposed to pleasurable and highly arousing situations (e.g., brisk exercise) as well as unpleasant and highly arousing situations (e.g., a
crowded train in which escape is difficult) to elicit interoceptive cues and associated fear structures involved in panic attacks. Exposure to emotionally arousing situations may more completely elicit one’s fear structure and result in faster extinction of associations between arousal cues and panic attack responses (Lang, Melamed, & Hart, 1970).

Another implication of the present data is suggested by the emotion- and color-word Stroop task comparison. Computerized attention training interventions have been successfully used by several researchers to modify attentional bias and reduce symptoms of psychopathology. For example, MacLeod, Rutherford, Campbell, Ebsworth, and Holker (2002) established that attention can be trained away from threat stimuli in nonclinical anxiety (measured with the State-Trait Anxiety Inventory, Spielberger et al., 1968) using a dot probe paradigm in which the probe is presented more frequently in the location of a neutral than threatening stimulus. Using a clinical sample and a dot-probe task, Amir, Beard, Burns, and Bomyea (2009) assigned GAD participants to a condition in which the probe was presented more frequently in the location of a neutral than threatening stimulus. GAD participants showed reductions in attentional bias to threat and a decrease in anxiety symptoms, whereas those assigned to a control condition did not. Present data suggest that the nature of neutral stimuli determines whether preferential processing of emotional stimuli is apparent. If attentionally-demanding (i.e., congruent and incongruent stimuli from the color-word Stroop task) neutral stimuli are used in attention training interventions, training attention toward neutral and away from threatening or unpleasant stimuli may not work, or may not work as quickly as interventions using neutral stimuli with fewer processing demands. This is an issue that has not yet been studied in attention training interventions but has implications for the generality of attention to emotional over neutral information.
Furthermore, to date attention training paradigms have not systematically considered the role of emotional arousal nor explored whether training attention away from emotionally arousing pleasant stimuli might also result in e.g. lowered self-reported anxiety or depression symptoms. For example, in the case of Panic Disorder, ostensibly pleasant cues associated with physiological arousal such as exercise (e.g., McNally, 1990) or relaxation (e.g., Adler, Craske, & Barlow, 1987) can trigger panic attacks. In the case of Major Depressive Disorder, under-processing of pleasant stimuli (e.g., happy faces, Joormann & Gotlib, 2007) may serve a perceived, short-term protective function (e.g., avoid social rejection, Coyne, 1976). Given present findings of early and later attentional biases for emotionally arousing stimuli in anxiety and for unpleasant valence and emotionally arousing stimuli in depression, future attention-training interventions may benefit from using paradigms that target emotional arousal more broadly and investigate both early sensory and later elaborative attentional processing more carefully, in order to explore the conditions under which early and/or later attentional bias is modifiable.

Anxiety and depression are both characterized by disrupted attention and are likely to show deficits in task contexts involving distracting or task-irrelevant emotional and non-emotional stimuli. Present data show that emotional information is not always preferentially processed in anxiety and depression and that preferential processing may depend on the processing demands of neutral stimuli. Systematic examination of the role of emotional valence, emotional arousal, and neutral and emotional stimulus processing demands is crucial to understanding so-called “preferential” attention for emotional stimuli in anxiety, depression, and comorbidity. Such work can yield insights into cognition-emotion interactions in
psychopathology that may improve understanding of the etiology and treatment of these disorders.
### CHAPTER 5

#### TABLES AND FIGURES

Table 1. Questionnaire Scores Used in Group Selection

<table>
<thead>
<tr>
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<th>MASQ-AA</th>
<th>MASQ-AD</th>
<th>PSWQ</th>
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<tbody>
<tr>
<td>Comorbid</td>
<td>42 (6.8)</td>
<td>27 (3.7)</td>
<td>71 (6.1)</td>
</tr>
<tr>
<td>Anxious Apprehension</td>
<td>21 (2.3)</td>
<td>13.2 (2.5)</td>
<td>68 (4.6)</td>
</tr>
<tr>
<td>Anxious Arousal</td>
<td>37 (3.8)</td>
<td>15 (2.0)</td>
<td>38 (8.3)</td>
</tr>
<tr>
<td>Anhedonic Depression</td>
<td>22 (2.5)</td>
<td>24 (2.8)</td>
<td>36 (9.0)</td>
</tr>
<tr>
<td>Control</td>
<td>21 (2.3)</td>
<td>13 (2.5)</td>
<td>38 (8.6)</td>
</tr>
</tbody>
</table>

Note. Questionnaire scores (mean (SD)) for each group. The anxious apprehension and comorbid group scored higher than the other three groups on the Penn State Worry Questionnaire (PSWQ; Sidak $ps < .001$). The anxious arousal and comorbid group scored higher than the other three groups on the Mood and Anxiety Symptom Questionnaire Anxious Arousal scale (MASQ-AA; Sidak $ps < .001$). The anhedonic depression and comorbid group scored higher than the other three groups on the MASQ Anhedonic Depression scale (MASQ-AD; Sidak $ps < .010$).
Figure 1. Top: Grand-average event-related potential waveforms for representative frontocentral sensors for the emotion-word Stroop task, highlighting N400. Blue, black, and red tracings represent pleasant, neutral, and unpleasant stimuli, respectively. Stimulus onset was at time = 0 ms. Bottom: Grand-average event-related potential waveforms for representative posterior sensors for the emotion-word Stroop task, highlighting P100, N200, and P300. Blue, black, and red tracings represent pleasant, neutral, and unpleasant stimuli, respectively. Stimulus onset was at time = 0 ms.
Figure 1 (continued)
Figure 2. Top: Grand-average event-related potential waveforms for representative frontocentral sensors for the color-word Stroop task, highlighting N400. Blue, black, black dashed, and red tracings represent congruent, neutral within congruent blocks, neutral within incongruent blocks and incongruent stimuli, respectively. Stimulus onset was at time = 0 ms. Bottom: Grand-average event-related potential waveforms for representative posterior sensors for the color-word Stroop task, highlighting P100, N200, and P300. Blue, black, black dashed, and red tracings represent congruent, neutral within congruent blocks, neutral within incongruent blocks, and incongruent stimuli, respectively. Stimulus onset was at time = 0 ms.
Figure 2 (continued).
Figure 3. N200 amplitude and P300 latency in the emotion-word Stroop task. Error bars represent 1 SE. Top: N200 emotional arousal effect in the anxious apprehension group and emotional valence and emotional arousal effects in the anhedonic depression group. Bottom: P300 latency emotional arousal effect in the anxious arousal and anhedonic depression group.
Figure 4. N200 and P300 amplitude in the comparison of emotion- and color-word Stroop tasks. Error bars represent 1 SE. Top: N200 amplitude is larger for incongruent than emotionally arousing stimuli in anxious arousal men and control women. Bottom: P300 amplitude is larger for incongruent stimuli in the right than left hemisphere in comorbid men and the anxious arousal group. P300 amplitude is larger for incongruent than emotionally arousing stimuli in comorbid women. P300 amplitude is larger for incongruent than emotionally arousing stimuli in the right hemisphere only in the anxious apprehension and control groups.
FOOTNOTES

1 Note that portions of the material in this chapter has been published elsewhere (Sass et al., 2010).

2 Analyses reported within the emotion-word Stroop task (addressing hypothesis 1) focus on an N=64 subset of 128 neutral trials. Omnibus results did not differ when using the full set of 128 neutrals, except in one case. Specifically, the Group x Gender x Hemisphere interaction for P100 amplitude became a trend, $F(4, 120) = 2.19, p = .074$ (previously $p = .049$). All other effects, including critical tests of hypotheses, remained unchanged.

3 Analyses reported comparing the emotion- and color-word Stroop tasks (addressing hypotheses 2 and 3) focus on an N = 32 subset of N=64 pleasant and N=64 unpleasant trials. Omnibus results did not differ when using the full set of pleasant and unpleasant trials, except in one case. The Group x Condition effect, $F(1, 120) = 2.08, p = .070$, became a trend (previously $p = .046$). The Group x Gender x Condition interaction, $F(1, 120) = 2.77, p = .030$, remained unchanged, as did all other effects and critical tests of hypotheses.

4 Total number of participants was 130 after exclusion for the following reasons: a) more than 5% of channels discarded due to artifact ($N = 4$) and b) amplitude values more than 3 SD from the mean for a given component at more than two electrode sites ($N = 8$).
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