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## An Electrophysiological Examination of Attentional Biases to Emotional Faces in Depression and Social Anxiety

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**AN ELECTROPHYSIOLOGICAL EXAMINATION OF ATTENTIONAL BIASES TO  
EMOTIONAL FACES IN DEPRESSION AND SOCIAL ANXIETY**

by

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## **ABSTRACT**

### **AN ELECTROPHYSIOLOGICAL EXAMINATION OF ATTENTIONAL BIASES TO EMOTIONAL FACES IN DEPRESSION AND SOCIAL ANXIETY**

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Cognitive theories have proposed that major depressive disorder (MDD) and social anxiety disorder (SAD) involve attentional biases toward and away from specific environmental stimuli. Research has often examined these biases in response to emotional facial expressions, but evidence of attentional biases is mixed. An event-related potential called the N2pc offers advantages over other measures of attentional bias and may clarify conflicting findings. Studies on the N2pc and social anxiety have found consistent results, but there is little work examining depression. Previous N2pc studies are limited by the types of emotional faces they use and by comparing attention for emotional faces only with neutral faces. Further, the effect of MDD-SAD comorbidity has not been thoroughly examined using the N2pc. In this study, undergraduate participants completed self-report questionnaires of depression and social anxiety symptoms. Electroencephalography and reaction time (RT) data were collected during a modified dot-probe task that put emotional faces (angry, disgust, sad, and happy) in direct competition with each other and with neutral faces. ANCOVAs predicting the N2pc and RT showed that no depression or social anxiety-related attentional biases were stronger for any one face type relative to biases for the other face types. However, multiple regressions predicting attentional bias toward specific face type showed that depression and social anxiety interacted to predict attentional biases. Depression was associated with an N2pc attentional bias toward sad faces when social anxiety was low. Social anxiety was related to an N2pc attentional bias away from angry faces at low depression and towards angry faces at high depression, and there was an

RT attentional bias away from disgust faces at low depression. Additionally, depression was related to an attentional bias away from neutral faces, while social anxiety was related to a bias toward them. These findings bolster evidence of a sad-related bias in depression and social threat-related biases in social anxiety but highlight the generally overlooked impact of co-occurring symptoms. Interventions for MDD and SAD should target attentional biases in a nuanced manner that considers comorbidity and patterns of both vigilance for and avoidance of social stimuli.

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## CHAPTER 1

### INTRODUCTION

Major Depressive Disorder (MDD) is defined by a period of significant depression consisting of nine possible symptoms including depressed mood and loss of interest (American Psychiatric Association [APA], 2013). MDD is the most common mental disorder in the United States, with a lifetime prevalence of 17-20% (Hasin et al., 2018; Kessler et al., 2012), and is a leading risk factor for disability (James et al., 2018; Mokdad et al., 2018) and suicide (Cavanagh et al., 2003; Chesney et al., 2014; Cho et al., 2016). Social anxiety disorder (SAD) often co-occurs with MDD and is characterized by excessive fear of being scrutinized and negatively evaluated in social situations (APA, 2013). On its own, SAD has lifetime prevalence of 13% in the United States (Kessler et al., 2012) and is associated with greater disability than other anxiety disorders (Hendriks et al., 2014; Moitra et al., 2011) as well as increased suicidal ideation (Buckner, 2017; Sareen et al., 2005) and substance abuse (Buckner et al., 2008; Buckner et al., 2013). MDD and SAD are more comorbid with each other than with other mental disorders, such that 15-27% of people with MDD and 27-58% with SAD have both disorders (Belzer & Schneier, 2004; Dalrymple & Zimmerman, 2007; Fava et al., 2000; Kessler et al., 1999). This comorbidity increases symptom severity and disability (Adams et al., 2016; Beltzer et al., 2004; Dalrymple & Zimmerman, 2007; Kessler et al., 1999) and can reduce treatment response (Koyuncu et al., 2019; Mulder et al., 2006).

In light of their comorbidity, research on MDD and SAD would benefit from examining the similar and unique aspects of these disorders, such as cognitive processes. Cognitive theories propose that both disorders are associated with systematic distortions of cognitive processes (i.e., cognitive biases). In particular, cognitive models of depression posit that it is associated with

cognitive biases toward depressive information (e.g., loss, failure; Beck, 1967; Lemoult & Gotlib, 2019). In social anxiety, theories suggest cognitive biases emphasize potential social threats and a negative image of one's social performance (Clark & McManus, 2002; Heimberg et al., 2010). Further, theories suggest both disorders involve impaired cognitive processing of positive information (Disner et al., 2011; Heimberg et al., 2014). One cognitive process through which these biases manifest is attention (i.e., attentional biases; Disner et al., 2011; Clark & McManus, 2002). For several decades, attentional bias research has increased our understanding of the mechanisms of depression and anxiety (Gibb et al., 2015). Attentional bias research has particularly provided insight at the intersection of three domains of the Research Domain Criteria framework for studying mental disorders (Insel, 2014), namely the cognitive system, negative valence systems, and positive valence systems (Amir et al., 2016; Gibb et al., 2015). Importantly, this research has led to MDD and SAD treatments such as attentional bias modification, attention-focused neurofeedback, and positive affect interventions (Craske et al., 2016; Hereen et al., 2015; Kimmig et al., 2019; Mennen et al., 2019; Taylor et al., 2017). However, methodological limitations and the paucity of studies comparing depression and social anxiety have constrained the impact of attentional bias research. The current study aimed to address these issues and advance the attentional bias literature.

### **Selective Attention**

Attentional biases are best appreciated through the framework of selective attention. Humans can only attend to a finite number of external stimuli at one time (Broadbent, 1958; Cowan, 2001; Lavie, 2010). As the brain's attentional network preferentially highlights some visual information, other percepts are not represented in the visual cortex or brought into awareness (Marois & Ivanoff, 2005; Miller & Buschman, 2013). This neural process of focusing

on certain visual stimuli and/or suppressing others is called selective visual attention (simply referred to as *selective attention* in this document; Theeuwes, 1993). But how does the human brain select what information captures attention? Research has identified two broad influences on the selection of stimuli for attention: bottom-up factors and top-down factors. Bottom-up factors are the physical properties of the external stimulus (e.g., color and orientation), while top-down factors are cognitive processes from within the person (e.g., one's goals and prior experiences; Corbetta & Shulman, 2002; Miller & Buschman, 2013; Rauss & Pourtois, 2013). For example, bottom-up factors such as spatial isolation and color may draw attention toward a lone person who enters a room while wearing a red hat, while top-down factors, such as engagement in a conversation, will also influence whether the red-hatted person draws attention. Top-down attentional factors may be either voluntary and intentional (e.g., noticing several red hats in a crowd when actively searching for a person wearing a red hat) or involuntary and uncontrolled (e.g., searching a crowd for a person wearing a red hat but being distracted by a purple hat that matches your own; Gaspelin & Luck, 2018). While bottom-up and top-down factors have some distinct neural pathways and time-courses, they also work together (Buschman & Miller, 2007; Corbetta & Shulman, 2002; Lu & Han, 2009; Sarter et al., 2001; Theeuwes, 2010) and interface within the visual and posterior parietal cortices (Bisley & Goldberg, 2010; McMains & Kastner, 2011; Melloni et al., 2012; Qiu et al., 2007). As such, the determination of which information will be captured by attention rests on both bottom-up and top-down processes.

The flexible interplay between bottom-up and top-down attentional factors leads to individual differences in selective attention (Rauss & Pourtois, 2013). For example, the red hat of a person entering a room may be salient enough to partially draw attention for many people, but the extent of attentional capture may be even greater for someone who is fond of the color

red. One area in which bottom-up and top-down factors affect individual differences in selective attention is with emotional stimuli (Pourtois et al., 2013). Research has shown that attention is modulated by the emotion-related bottom-up properties of stimuli, such as simple emotion-eliciting shapes (Larson et al., 2009) and the arousal level or valence of images (Nummenmaa et al., 2009; Schupp et al., 2003; Stefanics et al., 2012; Willson & MacLeod, 2003). Likewise, top-down factors such as task goals (Hahn & Gronlund, 2007; Schupp et al., 2007), emotional state (Laco et al., 2020; Vogt et al., 2011), and emotion regulation strategy (Langeslag & van Strien, 2018; Vogt & De Houwer, 2014) impact selective attention for emotional stimuli. Through a combination of bottom-up and top-down factors, emotion can help drive selective visual attention (Compton, 2003).

To the extent that emotion-related top-down factors (e.g., emotional states) are associated with corresponding trait-level individual differences (e.g., emotional disorders), such individual differences should be associated with unique patterns of selective attention. In support of this, researchers have found that differences in selective attention to emotional stimuli are associated with individual differences in, for example, psychopathology (Jang et al., 2016; Joormann & Gotlib, 2007; Waters et al., 2015), trait emotion regulation (Arndt & Fujiwara, 2012; Dennis et al., 2009; Kim et al., 2016), personality (Sadeh et al., 2011; von Ceumern-Lindenstjerna et al., 2010), and trauma history (McCoy et al., 2015; Pollak & Tolley-Schell, 2003). In other words, these individual differences are associated with specific attentional biases. Understanding these attentional biases provides insight into the cognitive mechanisms of emotional dysfunction, which has been incorporated into prominent theories of depression and social anxiety.

## **Attentional Bias Theory**

### ***Theories of Attentional Bias in Depression***

Cognitive theories of depression posit that people with depression will have cognitive biases that emphasize negative information and deemphasize positive information (Disner et al., 2011; Lemoult & Gotlib, 2019). Beck and colleagues' cognitive model (Beck, 1967; Disner et al., 2011) proposes that adverse events and other depression risk factors (e.g., genetics) cause people to develop negative schemas about themselves, others, and their future. When internal or environmental stressors activate the previously developed negative schemas, individuals engage in attentional patterns that align with those negative schemas. As such, individuals will have biased attention toward negative (e.g., rejecting or ominous) information and away from positive (e.g., accepting or hopeful) information, which heightens depressive symptoms and strengthens negative schemas (Disner et al., 2011). Lemoult and Gotlib's (2019) cognitive theory proposes that attentional bias may lead to depression directly but also indirectly by creating dysfunction in the cognitive strategies used to regulate emotions (e.g., reappraisal and distraction). They further posit that depression impairs cognitive control abilities, which serves to exacerbate attentional biases and, in turn, depression. These cognitive theories highlight that attentional biases contribute to the onset of depression as well as help maintain it over time (Disner et al., 2011; Lemoult & Gotlib, 2019). As such, examining attentional biases in depression may be important for understanding the development and treatment of the disorder.

### ***Theories of Attentional Bias in Social Anxiety***

Heimberg and colleagues' cognitive theory of SAD holds that the visual attention of people with social anxiety is biased toward noticing threatening social information in the environment (Heimberg et al., 2010; Rapee & Heimberg, 1997). For example, a socially anxious

individual may preferentially attend to other people's furrowed brows or blank expressions and interpret them as negative judgment or boredom, respectively. This theory proposes that socially anxious individuals simultaneously believe that acceptance by others is highly important and that negative evaluation by others is highly likely. As such, these individuals are vigilant for external cues that will confirm that others do indeed negatively evaluate them (Heimberg et al., 2010; Schultz & Heimberg, 2008). This detection of negative cues then prompts individuals to turn attention inward (i.e., self-focused attention) to monitor potentially embarrassing physiological (e.g., sweating) and behavioral (e.g., stammering) concerns, which maintain a feedback loop that continues attentional vigilance for negative evaluation and increases anxiety (Shultz & Heimberg, 2008). Critically, this feedback loop restricts cognitive processing resources that are needed to successfully engage in a social interaction (Heimberg et al., 2010).

Contrary to the interplay between attention to external and internal threat cues, Clark and Wells' (1995) model of social anxiety argues that internal focus of attention occurs without prior vigilance to external threat. This model highlights that thinking about previous social experiences prompts anticipatory anxiety when entering a social interaction, which triggers self-focused attention. Self-focus includes monitoring one's performance and observing one's anxiety, which preoccupy attention and reduce allocation of attention toward external cues. Reduced external attention then allows negative interpretation of other people's responses and feeds one's anxiety and negative self-image (Clark & McManus, 2002; Clark & Wells, 1995). Competing theories about attention being biased toward external or internal threat has influenced the vigilance-avoidance hypothesis. This hypothesis states that socially anxious individuals' attention is initially—and automatically—biased toward social threat but is subsequently biased to avoid the threat as exposure to it continues (Vassilopoulos, 2005). Although theories disagree



on the exact nature of attentional bias in social anxiety, they agree that attentional biases play an important role in the etiology, maintenance, and treatment of SAD.

## **Attentional Bias Research**

### ***Attentional Bias in Depression***

Attentional bias research has been conducted most often with behavioral reaction time tasks. In these tasks, bias in attention allocation is assumed based on how quickly participants respond to negative (e.g., sad) or positive (e.g., happy) stimuli compared to neutral stimuli. For example, many studies have tested attentional bias using an emotional Stroop task. The original, non-emotional Stroop task presents color words written in different colors of ink (e.g., “red” written in blue ink) and asks individuals to name the color of the ink and inhibit saying the written color. The emotional Stroop task uses emotional and neutral words, instead of color words, and participants must still name the color of the ink. In one of the first studies of attentional bias in depression, Gotlib & McCann (1984) asked depressed and non-depressed participants to complete an emotional Stroop task that used depressive, manic, and neutral words. The study found that depressed individuals took longer to name the colors of depressive words than other words, indicating they were more distracting and attention was biased towards them. In contrast, the non-depressed individuals’ reaction times were not affected by word type (Gotlib & McCann, 1984). Researchers have also widely used the emotional dot-probe task to examine attentional bias. In an early emotional dot-probe, study participants viewed pairs of face photographs (one neutral and one emotional) on a computer and, after the pictures disappeared, pressed a button to indicate whether a dot was revealed behind the neutral or emotional face (Gotlib, Krasnoperova, et al., 2004). Results showed that the depressed group responded more quickly to the probe when it appeared behind sad faces, compared to happy and angry faces,

indicating greater attention to the sad faces (Gotlib, Krasnoperova, et al., 2004). Overall, many reaction time studies have demonstrated that current depression is related to an attentional bias toward negative stimuli (e.g., Broomfield et al., 2007; Gotlib & Cane, 1987; Gotlib, Kasch, et al., 2004; Joorman & Gotlib, 2007; Rinck & Becker, 2005), while others have failed to find this relation (e.g., Bradley, Mogg, & Lee, 1997; Elgersma et al., 2018; Gotlib et al., 1988; Krings et al., 2020; Mogg et al., 1993; Yovel & Mineka, 2005). There is also mixed evidence of whether depressed, compared to non-depressed, individuals show less attention toward positive stimuli, with some studies showing this effect (Erickson et al., 2005; Gotlib et al., 1988, Joorman & Gotlib, 2007; Zhong et al., 2011) and others not (Gotlib et al., 2004; Mogg et al., 1993). A meta-analysis of 29 Stroop and dot-probe studies found that depressed, compared to non-depressed, individuals did indeed display small, significant attentional biases toward depressive stimuli ( $d = 0.37$ ) and away from positive stimuli ( $d = -0.23$ ; Peckham et al., 2010). These effects were only apparent in the dot-probe tasks and not significant in the Stroop tasks (Peckham et al., 2010). In contrast, a more comprehensive meta-analysis of 47 Stroop studies found that depression was associated with large attentional biases toward both negative ( $g = 0.98$ ) and positive ( $g = 0.87$ ) words, suggesting increased attention to emotional stimuli in general (Epp et al., 2012). The inconsistency between the dot-probe and the Stroop results may reflect task differences, as the dot-probe often uses face stimuli (instead of words) and pairs emotional stimuli with neutral stimuli that compete for attention.

Although reaction time tasks have identified divergent attention allocation in people with depressive symptoms, they have significant limitations. First, interpretation of dot-probe and Stroop data is uncertain, as reaction time may reflect attention orienting, attention disengagement, or both (Eastwood et al., 2005; McTeague et al., 2011). Second, the emotional

Stroop effect may be influenced by showing blocks of semantically related words (e.g., sad words), which increases reaction time compared to blocks of words that are less related (e.g., general neutral words; Holle et al., 1997). Third, reaction time tasks may be confounded by cognitive or physiological processes that occur between selective attention and the behavioral response. Fourth, reaction time merely captures attention at one point in time. Although the dot-probe task has been regarded as the gold standard in the literature (Gupta et al., 2019; Thigpen et al., 2018), the dot-probe's reaction time measure consistently obtains very poor reliability (e.g., split-half reliability; Chapman et al., 2019; Kappenman et al., 2014; McNally, 2019; Van Bockstaele et al., 2020).

To overcome some of the limitations of reaction time data, some researchers have used eye tracking, which offers the particular advantage of monitoring attention continuously across time. In the first of such studies, Mogg and colleagues' (2000) participants completed an emotional dot-probe task while an eye tracker recorded the direction and latency of the initial orienting of their eyes. Results showed that depressed participants did not differ from anxious or control participants in their initial orienting toward sad, happy, or neutral faces nor in the speed at which they oriented towards those faces, suggesting no attentional bias. Results from subsequent eye tracking studies have been mixed, with some showing the predicted depression-related attentional biases for negative (e.g., Soltani et al., 2015; Klawohn et al., 2020) or positive (e.g., Arndt et al., 2014; Bodenschatz et al., 2019; Soltani et al., 2015) information and others showing no negative (e.g., Bodenschatz et al., 2019) or positive (e.g., Lazarov et al., 2018) attentional biases. Eye tracking has permitted investigation into the time course of attentional biases through the use of free-viewing paradigms, which present a stimulus or stimuli for multiple seconds while participants freely gaze upon them with no instructions about where to

look. For example, Lazarov and colleagues (2018) examined attention allocation to picture arrays consisting of happy and sad faces across 8-second trials. They found that depressed and non-depressed individuals did not differ in their initial orienting to the faces but that depressed, compared to non-depressed, individuals spent more time maintaining attention on sad faces over time. Other studies have found similar patterns of a delayed attentional bias in absence of an early attentional bias (e.g., Caseras et al., 2007; Sanchez et al., 2013). Indeed, two eye tracking meta-analyses found that depression did not affect early attention to negative stimuli but affected the maintenance of attention ( $g_s = 0.46$  to  $0.66$ ; Armstrong & Olatunji, 2012; Suslow et al., 2020). These meta-analyses further showed less attentional maintenance for positive images ( $g_s = -0.51$  to  $-0.81$ ), with one of them showing a small effect of less initial attentional orienting to positive images ( $g = -0.24$ ; Armstrong & Olatunji, 2012). The more robust findings for later attention echo results seen in many reaction time tasks in which depressed individuals show no bias toward negative stimuli when they are presented for briefer durations (e.g., 14 or 100 ms) but do for longer durations (e.g., 500 ms or 1,000 ms; Bradley, Mogg, and Lee, 1997; Donaldson et al., 2007); Gotlib et al., 1988; Mathews et al., 1996; Mogg, 1995; Zhong et al., 2011).

Despite overcoming the limitations of reaction time tasks, eye tracking tasks can only measure overt attention, which is independent of the covert attention that takes place without eye movement (Gregoriou et al., 2012; Hunt & Kingstone, 2003). Measuring covert attention is important because of the “decision period” of about 200 ms prior to the first eye movement toward stimuli (Fernandes et al., 2018, p. 74). As such, eye tracking may miss the initial orienting of attention (Singh et al., 2015). Further, evidence suggests that the measure of initial orienting captured by eye tracking has poor reliability (Lazarov et al., 2018; Wermes et al., 2017). To obtain a more precise measure of covert attentional biases in depression, researchers

have turned to event-related potentials (ERPs). ERPs are electrical brain responses to discrete stimuli and are known to be modulated by the emotional aspects of stimuli, including faces (Schindler & Bublatzky, 2020). ERPs are extracted from continuous electroencephalography (EEG), such that they can measure early attention (beginning < 300 ms post-stimulus) as well as later, more elaborative attention (beginning > 300 ms post-stimulus). ERP nomenclature often combines the polarity of the ERP amplitude (either positive [P] or negative [N]) with its general timing (e.g., 100 ms [1] or 200 ms [2] following a stimulus), as in the P1 or N2. By using neural, rather than behavioral, data that is continuous and has high temporal precision, ERPs can overcome the limitations of reaction time tasks and capture the covert attention not available in eye tracking data.

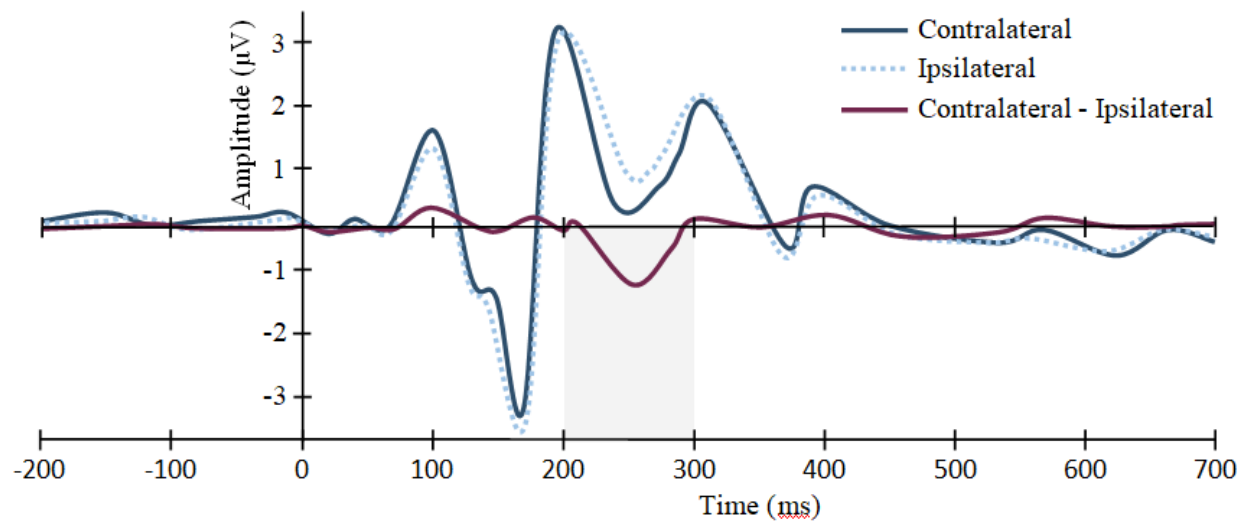
To examine early attentional bias in depression, Dai and Feng (2012) asked participants to judge the intensity of facial expression photos while measuring the P1 and P2, which are larger when allocating attention toward a stimulus (see Gupta et al., 2019). Depressed, but not control, participants had larger P1 and P2 amplitudes to sad faces compared to other faces, which was interpreted as indicating heightened attention to sad emotion (Deng & Feng, 2012). Using a variety of early attention ERPs (e.g., P1, P2, N1, N170, N2) additional studies have found evidence of attentional bias toward negative stimuli (e.g., Chen et al., 2014; Dai et al., 2016; Hu et al., 2017; Ruohonen et al., 2020; Wu et al., 2015; Zhang et al., 2016). Other studies have found that early ERPs (namely, the N1, N2, and P2) are *reduced* in response to negative stimuli during tasks that require inhibiting attention (Krompinger and Simons, 2009; Dai & Feng, 2011, Yao et al., 2010). In the context of these tasks, authors interpreted the reduced ERP amplitudes to indicate difficulty controlling attention due to negative affective distractors. Despite evidence of a negative attentional bias in depression, some ERP studies did not find this bias early in

attention (Ao et al., 2020; Bistricky et al., 2014; Deldin et al., 2000; Yu et al., 2017). ERP data have also supported the connection between depression and reduced early attention toward positive stimuli (Ao et al., 2020; Chen et al., 2014; Dai & Feng, 2011; Zhong et al., 2011; Tang et al., 2011; Zhang et al., 2016; Zhao et al., 2015), but some studies have found evidence of *increased* attention toward positive stimuli or both positive and negative stimuli (Dai & Feng, 2012; Dai et al., 2016; Jaworska et al., 2012; Ruohonen et al., 2019; Xue et al., 2017; Zhao et al., 2015). Additional studies have demonstrated depression-related attentional biases in later attention, as indexed by a dysfunctional P3 response to negative stimuli in depressed individuals (Ao et al., 2020; Ilardi et al., 2007; Krompinger and Simons, 2009; Li et al., 2018; Ohira, 1996; Yu et al., 2017; Zhang et al., 2016). However, some studies failed to find a P3 effect (Bistricky et al., 2014; Dai & Feng, 2011). Overall, ERP studies have given more confidence to the idea of an early, in addition to late, negative attentional bias in depression (see Delle-Vigne et al., 2014) as well as a bias either away from or toward positive information.

Methodological limitations restrict interpretation of these ERP findings. Many study tasks present only one stimulus at a time, and so, do not directly show whether attention is biased toward one stimulus versus another. Even when studies show multiple stimuli simultaneously, the ERPs may respond to any or all of the stimuli on the screen, reducing confidence in detecting a specific attentional bias. Further, interpretation of ERPs can be limited by the various ERPs and cognitive processes that overlap each other in time (Luck, 2014; Perez et al., 2012). Fortunately, these limitations can be reduced through the contralateral-control method, which leverages the fact that input from one visual hemifield is primarily processed in the opposite (contralateral) hemisphere of the brain (Gratton, 1996). ERPs that use the contralateral-control method compare electrodes on the left side of the scalp to those on the right for a within-subjects

measure of preferential processing of a particular hemifield. An ERP called the N2-posterior-contralateral (N2pc) uses this method to infer attention allocation with more confidence than other ERPs (Luck, 2014). In one of the first N2pc studies, Luck and Hillyard (1994) used a visual search task in which several rectangles were presented on both sides of a screen. On half the trials, all rectangles in both visual hemifields were identical; on the other trials, a rectangle in one hemifield was unique in color or shape. While maintaining their gaze on the center of the screen, participants judged the presence or absence of a unique rectangle. Results showed that the average N2pc amplitude was larger at electrodes contralateral to the unique rectangles compared to electrodes ipsilateral to them (i.e., on the same side), suggesting the N2pc is larger for attended items and reflects the location of selective attention (Luck & Hillyard, 1994).

The N2pc is measured from 200 to 300 ms after stimulus onset at posterior electrodes sites over the visual cortex (Luck, 2012). It employs the contralateral-control method by subtracting the average voltage (in microvolts [ $\mu\text{V}$ ]) at the electrodes ipsilateral to the stimulus from those contralateral to the stimulus (i.e.,  $\mu\text{V}_{\text{contra}} - \mu\text{V}_{\text{ipsi}}$ ; see Figure 1; Luck, 2012). Any deviation above zero in this formula indicates that the brain has covertly focused visual attention toward the contralateral visual hemifield (Luck, 2012). Indeed, studies support interpreting the N2pc as an index of the spatial location of focused attention rather than other attentional processes (e.g., preparatory shifts in attention; Kiss et al., 2008; Zivony et al., 2018). The neural source of the N2pc has been localized to the occipitotemporal cortex within the ventral visual pathway and specifically to visual area V4 and the lateral occipital complex (Hopf et al., 2006; Luck, 2012), which are involved in spatial visual attention (Murray & Wojciulik, 2004; Roe et al., 2016).

**Figure 1***N2pc*

*Note.* Contralateral - ipsilateral represents the N2pc waveform. Gray box indicates the timing of the N2pc.



The N2pc offers several advantages over other ERPs. The within-subject comparison between the two hemispheres helps control for basic sensory and general cognitive processes elicited by a task (Gratton, 1996; Luck, 2012; Perez et al., 2012). As such, the N2pc measures selective attention while controlling for other relevant individual differences such as cognitive control and general attention to the study task. In contrast to some ERPs, the N2pc is not impacted by stimulus probability or feature dimension (Luck, 2012). The contralateral-control method isolates the N2pc from other non-lateralized ERPs that overlap it in time, which provides confidence that the N2pc represents the inferred underlying process (i.e., selective allocation of attention; Kappenman & Luck, 2011). Together, these properties of the N2pc increase the signal-to-noise ratio and improve the chances of detecting an attentional bias if one exists. Indeed, research shows that the N2pc possesses good internal consistency (Kappenman et al., 2014, 2015; Reutter et al., 2019), including in studies on depression ( $r_{\text{split-half}} = .84-.92$ ; Gibb et al., 2016) and social anxiety ( $r_{\text{odd-even}} = .83-.84$ ; Reutter et al., 2017).

Despite these advantages of the N2pc, only two studies have reported on its association with depression. One study recruited children at risk or not at risk of depression (as indicated by maternal MDD history) and had them complete a spatial-cueing task, which was similar to a dot-probe task but presented only one face (angry, happy, sad, and neutral) at a time rather than two (Gibb et al., 2016). Results showed that children at risk for depression, compared to those not at risk, had a smaller (i.e., less negative) N2pc amplitude for sad faces, which indicated reduced attention allocation toward sad faces (Gibb et al., 2016). The other N2pc study focused on attentional bias in adults with attention-deficit/hyperactivity disorder, and a supplemental finding showed that there was no correlation between the N2pc and depression severity (Shushakova et al., 2018). However, authors combined N2pc amplitude across negative and positive words,

obscuring the effects of specific emotions (Shushakova et al., 2018). Given the N2pc results in children, the current study aims to advance the literature as the first to use the N2pc to examine the association between current depression and attentional bias to specific stimuli in an adult sample.

### ***Attentional Bias in Social Anxiety***

Reviews of research on attentional biases conclude that effects are more consistent or robust in anxiety disorders than in depression (Gotlib & Joorman, 2010; Mobini & Grant, 2007; Menika et al., 1998; Mogg & Bradley, 2005). Anxiety-related attentional bias is often examined in response to threatening stimuli, with social anxiety research focusing on social threat (e.g., angry or disgust faces; Bar-Haim et al., 2007). As with depression research, studies first used reaction time tasks to evaluate attentional bias in social anxiety, and there are many studies showing that social anxiety is associated with attentional bias toward socially threatening stimuli in both the Stroop task (e.g., Carrigan et al., 2004; Grant & Beck, 2006; Hope et al., 1990; Spector et al., 2003) and the dot-probe task (e.g., Amir et al., 2003; Klumpp & Amir, 2009; Mogg & Bradley, 2002; Musa et al., 2003). In an early dot-probe study that examined attentional bias in social anxiety, Asmundson and Stein (1996) presented either a social threat word (e.g., foolish) or a physical threat word (e.g., dizzy) paired with a neutral word, followed by the probe. Participants with SAD responded to the probe faster when it was behind social threat (but not physical threat) words, which authors interpreted as a bias to selectively attend to social threat specifically. Indeed, studies typically find bias is specific to social threat (Hope et al., 1990, Lundh & Öst, 1996; Mattia et al., 1993; Musa et al., 2003; Spector et al., 2003) but some have found bias to physical (Vassilopoulos, 2005) or depressive (Grant & Beck, 2006) threat in addition to social threat. In a meta-analysis of reaction time tasks, eight social anxiety studies

contributed to a medium within-group effect ( $d = 0.59$ ) of bias toward social threat and a medium between group effect ( $d = 0.46$ ; Bar-Haim et al., 2007). However, this meta-analysis did not include several studies that found no effect of social anxiety on threat-related attentional bias (Bradley, Mogg, Millar et al., 1997; Gotlib, Kasch, et al., 2004; Horenstein & Segui, 1997; Mansell et al., 2002) and subsequent null findings have been reported (e.g., LeMoult & Joormann, 2012; Mueller et al., 2009; Ononaiye et al., 2007; Schofield et al., 2013). A more recent meta-analysis of 11 dot-probe studies found that socially anxious individuals, compared to controls, had a medium attentional bias toward threat stimuli ( $g = 0.53$ ), though the social anxiety within-group effect was small ( $g = 0.21$ ; Bantín et al., 2016).

Although some reaction times studies have provided initial evidence of an attentional bias toward threat in social anxiety, contradictory results have called this bias into question. Examining stimulus duration has provided insight into heterogeneous effects. For example, in a dot-probe task, Mogg and colleagues (2004) presented face pairs for two exposure durations (500 ms and 1,250 ms; Mogg et al., 2004). The SAD group in this study exhibited faster response times to angry faces, compared to happy and neutral faces, only in the 500 ms condition, which suggested that the bias toward threat was only during the initial attentional orienting (Mogg et al., 2004). In line with this conclusion, Bantín and colleagues' (2016) dot-probe meta-analysis found that threat-related attentional bias occurred primarily in early (500 ms and 600 ms) rather than late (1,000 ms and 1,250) attention. The effect sizes showed that only early attention had a significant within-subject effect ( $g_{\text{social anxiety}} = 0.24$ ,  $g_{\text{controls}} = -0.22$ ) as well as a more robust between-group effect in early attention ( $g_{\text{early}} = 0.60$ ,  $g_{\text{late}} = 0.38$ ). Attentional bias toward threat in people with social anxiety has also been shown at even shorter stimulus durations (<200 ms; Mogg & Bradley, 2002; Stevens et al., 2009).

Attentional bias for positive faces has also been examined using reaction time, such as in several studies that tested the ability to detect negative and positive faces in a crowd of neutral faces. While two such studies found differences in reaction times to negative versus positive faces, between-group effects appeared to be driven by slower responses to positive faces rather than faster responses to negative faces (Eastwood et al., 2005; Gilboa-Shechtman et al., 1999) and another study found no difference in reaction times at all (Juth et al., 2005). Reduced attentional bias to positive versus neutral faces in social anxiety has also been found in dot-probe studies (Mueller et al., 2009; Pishyar et al., 2004; Taylor et al., 2010), but many studies have found null effects for positive faces (Amir et al., 2003; Bradley, Mogg, Millar, et al., 1997; Gotlib, Kasch, et al., 2004; Pineles & Mineka, 2005) or attentional bias toward both positive and negative faces (Rossignol et al., 2012; Stevens et al., 2009). Although some reaction time research suggests a possible bias away from positive faces in people with social anxiety, more research contradicts this conclusion.

Eye tracking research has attempted to tease apart social anxiety effects on attentional bias across time. An early meta-analysis examined seven free viewing task studies in which participants freely gaze at two to four faces of various expressions. There was a small, but significant, effect of social anxiety on more initial orienting toward threatening faces ( $g = 0.37$ ) but no effect on maintenance of attention across the first two seconds of stimulus presentation ( $g = 0.05$ ; Armstrong & Olatunji, 2012). This suggested an initial vigilance toward threat without subsequent avoidance, though studies were noted to be highly heterogeneous. Indeed, although studies have supported the view that social anxiety is associated with initial orienting toward social threat (e.g., Bradley et al., 2000; Gamble & Rapee, 2010; Stevens et al., 2011), many have not (e.g., Chen et al., 2012; Fernandes et al., 2018; Liang et al., 2017; Lazarov et al., 2016;

Schofield et al., 2013; Singh et al., 2015; Wermes et al., 2018). Dysfunction during initial orienting may also not be emotion-specific, as socially anxious individuals' initial orienting may also be vigilant for (Wieser et al., 2009) or avoidant of (Byrow et al., 2016; Mühlberger et al., 2008) emotional stimuli in general (i.e., both positive and negative faces). Regarding attentional maintenance, some studies have found that social anxiety is associated more time attending to threatening faces across the early seconds of presentation (Lazarov et al., 2016; Liang et al., 2017; Schofield et al., 2013; Schofield et al., 2012;). However, other studies have found avoidance of threat (Lange et al., 2011) or no effect at all (Gamble & Rapee, 2010). The mixed findings provide little support for the vigilance-avoidance for threatening faces (i.e., initial vigilance followed by avoidance), but some studies have found evidence of vigilance-avoidance for emotional faces in general (Garner et al., 2006; Wieser et al., 2009).

In line with the inconsistent eye tracking data, a meta-analysis of 30 eye tracking studies found only a small effect of social anxiety on early attentional bias toward angry faces ( $g = 0.21$ ; Günther et al., 2021). This meta-analysis found no early attentional bias involving happy versus neutral faces ( $g = 0.05$ ; Günther et al., 2021). However, some studies have demonstrated reduced sustained attention toward happy faces in people with social anxiety (e.g., Chen et al., 2012; Liang et al., 2017; Schofield et al., 2013), which has contributed to the theory that people with SAD avoid positive, in addition to negative, evaluation (Chen & Clarke, 2017; Weeks & Howell, 2012). In contrast to the above research in which multiple faces compete for attention, studies that present single faces and examine eye contact have been more consistent (for reviews, see Chen & Clarke, 2017; Chen et al., 2020). Indeed, meta-analytic effect sizes show that socially anxious people avoid eye contact with negative ( $g = -0.67$ ) and positive ( $g = -0.49$ ) faces (Günther et al., 2021). Eye tracking has also demonstrated that socially anxious individuals

engage in heightened visual scanning of faces ( $g = 0.42$ ; Günther et al., 2021), perhaps indicating excessive monitoring of one's environment (Chen & Clarke, 2017). Overall, eye tracking research has indicated dysfunctional eye gaze patterns across time in socially anxious individuals, though studies provide little consensus on the exact nature of the attentional bias.

As with the depression literature, researchers have employed ERPs in an attempt to better understand attentional bias in social anxiety. In one ERP dot-probe study, researchers examined P1 amplitude in response to angry-neutral and happy-neutral face pairs as well as the subsequent probe (Mueller et al., 2009). SAD was associated with a larger P1 for angry-neutral pairs compared to happy-neutral pairs and a smaller P1 for the probe that appeared in place of both angry and happy faces compared to neutral faces. These findings suggest a hypervigilance for threatening faces in early attention followed by avoidance of emotional faces in general (Mueller et al., 2009). However, many other studies have shown that the P1 amplitude of people with social anxiety is enhanced to non-negative faces as well, indicating early hypervigilance to all emotional faces (Rossignol, Campanella, et al., 2013; Rossignol, Campanella, et al., 2012) or to emotional and neutral faces (Hagemann et al., 2016; Helfinstein et al., 2008; Kolassa et al., 2007; Kolassa et al., 2009; Mühlberger et al., 2009; Peschard et al., 2013; Rossignol, Philippot, et al., 2012; Wieser & Moscovitch, 2015). Other studies have failed to find any social anxiety-related difference in P1 amplitude (Cao et al., 2017; Cui et al., 2021; Kanai et al., 2012; Kolassa & Miltner, 2006; Bar-Haim et al., 2005), though one showed an early P1 latency to angry faces, indicating faster attentional orienting (Bar-Haim et al., 2005). One study found *reduced* P1 (and P2) amplitudes to all faces in people with high social anxiety, though the study's task design encouraged reduced attention to the face (Rossignol, Fisch, et al., 2013). Despite inconsistencies, these P1 studies point to hypervigilance for emotional faces or faces in general.

The other early ERPs provide more mixed evidence of hypervigilance than the P1. The P2 is enhanced for people with social anxiety in response to all emotional stimuli (Helfinstein et al., 2008; Rossignol, Philippot, et al., 2012) or not enhanced at all (Hagemann et al., 2016; Peschard et al., 2013). The N170 is often found to be unrelated to social anxiety (Hagemann et al., 2016; Kolassa et al., 2007; Mühlberger et al., 2009; Peschard et al., 2013; Rossignol, Campanella, et al., 2012; Rossignol, Fisch, et al., 2013). However, some N170 studies have contradicted those null findings and noted either an enhanced (Cui et al., 2021; Kolassa & Miltner, 2006; Mueller et al., 2009) or reduced (Wieser & Moscovitch, 2015) N170 in response to faces. In slightly later attention, P3 studies typically show no evidence of bias (Bar-Haim et al., 2005; Fisch, et al., 2013; Kolassa et al., 2007; but see Sewell et al., 2008). However, more sustained attention appears biased toward threat, as evinced by the steady state visual evoked potential (ssVEP; McTeague et al., 2018; McTeague et al., 2011; Wieser et al., 2011; Wieser et al., 2012). Beyond the P1, early ERPs show quite mixed findings about attentional bias, but hypervigilance toward threat is evident in sustained attention.

To help clarify the attentional bias literature and more confidently isolate early attention allocation, several social anxiety studies have employed the N2pc. In the first social anxiety study to use the N2pc, Judah and colleagues (2016) administered a change detection task in which undergraduate students viewed picture arrays with two neutral faces on one side and two disgust faces on the other and were tasked to identify whether the faces changed later in the trial. The N2pc was larger (i.e., more negative) on the contralateral, compared to ipsilateral, side of disgust faces in the high social anxiety group only, which indicated increased attention for disgust faces (Judah et al., 2016). A subsequent N2pc study found attentional biases toward both threatening *and* positive faces in a visual search task that required participants to quickly identify

an angry or happy face among neutral faces (Wieser et al., 2018). The other three N2pc studies to examine social anxiety used the dot-probe task, but only included threat-neutral emotion face pairs and no positive faces (Reutter et al., 2017; Yuan et al., 2020; Yuan et al., 2021). These dot-probe studies found that the N2pc amplitude for threatening faces was more negative for people with higher social anxiety ( $r = -.25$ ; Reutter et al., 2017) or in a high social anxiety group ( $d = 0.47$ ; Yuan et al., 2020; Yuan et al., 2021). This N2pc literature shows a consistent link between social anxiety and early attentional bias to threat. However, previous studies have neglected to directly compare attentional biases for simultaneously presented emotional stimuli. In contrast, the current study will examine how social anxiety is related to attentional bias measured by the N2pc when an assortment of emotional faces are in direct competition with each other. Such an approach acknowledges the variety of faces vying for attention in social situations and will provide insight into whether attentional bias in social anxiety is specific to threat.

### ***Attentional Bias in Depression and Social Anxiety***

The ERP research on early attentional biases tends to indicate a bias toward depressive stimuli in depression and toward social threat in social anxiety. However, inconsistencies exist within the depression and social anxiety literatures, which may be partially attributed to the comorbidity between MDD and SAD. Comorbid depression has been shown to suppress the attentional bias toward threat in people with social anxiety (Grant & Beck, 2006; LeMoult & Joormann, 2012; Musa et al., 2003). For instance, Musa and colleagues (2003) administered a reaction time dot-probe task with social threat-neutral and physical threat-neutral word pairs and found that participants with high social anxiety showed an attentional bias toward social threat. However, participants high in both social anxiety and depression behaved like control participants, avoiding social threat (Musa et al., 2003). Anxiety researchers have speculated that



depression-related amotivation and psychomotor slowing may cause the suppression of the attentional bias (Mogg & Bradley, 2005; Mogg et al., 1993). However, other reaction time studies found an attentional bias toward threat in both comorbid MDD-SAD and SAD groups (Kircanski et al., 2015; Kishimoto et al., 2021) or after controlling for depression severity (Pishyar et al., 2004; Vassilopoulos, 2005). Two N2pc studies showed that the attentional bias toward threat in people with high social anxiety survived after controlling for depression severity (Judah et al., 2016; Wieser et al., 2018), but the effects of comorbidity on attentional bias to a broader set of facial expressions or on depression-related biases have not been explored with the N2pc.

Attentional biases in purely depressed or socially anxious individuals have also been directly compared in reaction time tasks. In a dot-probe task with happy, sad, and angry faces compared to neutral, participants with MDD were biased toward sad faces, while those with SAD showed no biases for any emotion, including threat (Gotlib, Kasch, et al., 2004). In contrast, an emotional Stroop task revealed a bias for social threat and depressive words in participants with high social anxiety, while those with high depressive symptoms had no bias (Grant & Beck, 2006). Further, one study found unique attentional biases for disorder specific words in both MDD and SAD (Rinck & Becker, 2005). Conflicting findings among reaction time tasks suggests the need to use more precise methods, like the N2pc.

### **Summary of the Literature**

Reaction time tasks were the first to examine attentional bias in emotional disorders. Among people with depression, these tasks tend to identify early attentional biases toward negative stimuli and either toward or away from positive stimuli (e.g., Epp et al., 2012; Peckham et al., 2010), while people with social anxiety often show a bias toward threat and perhaps a bias

away from positive stimuli (e.g., Bantin et al., 2016; Mueller et al., 2009). However, the reaction time literature is inconsistent and difficult to interpret because the method relies on a secondary motor response, conflates attentional orienting and disengagement (McTeague et al., 2011), and is unreliable (e.g., Chapman et al., 2019). Eye tracking paradigms were developed to more precisely identify attentional processes through continuous monitoring of eye movements. These studies have generally demonstrated that depression is associated with sustained attentional bias toward depressive stimuli and away from positive stimuli, while biases in attention orienting are not commonly found (e.g., Armstrong & Olatunji, 2012; Suslow et al., 2020). In social anxiety, there is some eye tracking evidence of an attentional bias toward social threat when orienting attention but not for sustained attention (e.g., Armstrong & Olatunji, 2012; Günther et al., 2021). Despite their contributions, eye tracking studies are often inconsistent, unable to measure covert attention (Singh et al., 2015), and do not reliably capture the initial orienting of attention (e.g., Lazarov et al., 2018).

Attention-related ERPs have enabled researchers to examine covert attention without relying on secondary behavioral responses. ERPs have provided evidence of an early attentional bias toward depressive stimuli and either away from or toward positive stimuli in people with depression. In social anxiety, early ERPs, particularly the P1, tend to show attentional bias toward any emotional facial expression or faces in general. As with the reaction time and eye tracking literature, the ERPs typically used to measure attentional bias in depression and social anxiety have demonstrated contradictory and null findings. Because these non-lateralized ERPs were unable to examine biases in attention for simultaneously presented stimuli, researchers have employed the contralateral-control method with the N2pc. In depression research, the only N2pc study to report on attentional biases for specific emotions showed a bias away from sad faces

among children at-risk for MDD (Gibb et al., 2016), while an additional study showed no relation between depression and an N2pc response to combined emotional stimuli (Shushakova et al., 2018). All five studies that examined the N2pc in people with social anxiety showed a bias toward socially threatening faces (Judah et al., 2016; Reutter et al., 2017; Wieser et al., 2018; Yuan et al., 2020; Yuan et al., 2021). Although this social anxiety research suggests a consensus, four of the studies used only one type of emotional stimuli, while the other study contaminated the emotionally weighted visual hemifield by simultaneously showing neutral faces in that hemifield (Wieser et al., 2018). Further, all of these studies directly compared emotional faces only to neutral faces. Research is needed to address limitations of the attentional bias literature by examining the N2pc in response to emotional faces that compete for attention and are relevant to both depression and social anxiety, allowing comparison of these often-comorbid symptoms.

### **The Current Study**

The first aim of this study was to observe the N2pc response to a variety of facial expressions that are in competition with each other. This expanded upon previous N2pc studies, which have compared emotional stimuli only to neutral stimuli and typically include only one type of emotional stimuli. To reach this aim, the study made a novel modification to the emotional dot-probe task in which five facial expressions were presented in direct competition with each other, two at a time. Given that the dot-probe task laterally presents two task-irrelevant stimuli, it fits well with the N2pc, which can be modulated by task-irrelevant stimuli (Burra & Kerzel, 2013; Eimer & Kiss, 2007) and requires stimuli in opposing visual hemifields. In the dot-probe task, a more negative N2pc indicated a larger attentional bias for one facial expression compared to all the others. While the N2pc was the primary outcome in the current study,

reaction time to the probe served as a secondary outcome, as is typical in ERP research using the dot-probe task.

The second aim was to test whether depression and social anxiety are associated with attentional biases to theoretically relevant facial expressions but not to other facial expressions. This was to contribute insight into the emotional specificity of attentional biases in depression and social anxiety as emotional facial expressions directly compete for attention. To meet this aim, the study task included facial expressions relevant to depression (happy, sad) and social anxiety (angry, disgust) as well as neutral faces. Depression was expected to be associated with increased attentional bias toward sad faces and reduced attentional bias toward happy faces, while social anxiety was expected to be associated with attentional bias toward disgust faces and angry faces.

The third aim was to examine the uniqueness of attentional biases in depression and social anxiety when accounting for each other as well as identify how the co-occurrence<sup>1</sup> of depression and social anxiety impact the pattern of attentional biases. This aim was to address the lack of N2pc research on the interaction of depression and social anxiety and help explain the heterogeneous findings in the broader literature on attentional bias to facial expressions. This interaction would thus test the inconsistent findings from previous literature about whether depression suppresses the attentional bias associated with social anxiety (e.g., Grant & Beck, 2006; LeMoult & Joormann, 2012). Depression-related attentional biases toward sad faces and away from happy faces were expected to persist across levels of social anxiety but be smaller at higher levels of social anxiety. Likewise, social anxiety-related attentional biases toward angry

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<sup>1</sup> The term “co-occurrence” is used here, and subsequently, as similar to but distinct from “comorbidity.” Whereas “comorbidity” refers to the diagnosis of multiple mental disorders, the current study will not apply diagnostic criteria to establish comorbidity. Instead, the study assesses the severity of depression and social anxiety and is thus suited to evaluate the extent to which they or do not “co-occur” on a continuous level.

and disgust faces were expected to persist across levels of depression but reduce at higher levels of social anxiety.

## CHAPTER 2

### METHOD

#### Participants

Participants were undergraduate psychology students from Old Dominion University. They were recruited through an online subject pool and participated in exchange for research credit. The target sample size was selected based on power analyses using G\*Power 3 (Faul, et al., 2007). The first power analysis examined the planned follow-up tests of the difference between two dependent sample correlations (G\*Power 3: *two dependent Pearson r's [common index]*; see Analyses). Reutter and colleagues' (2017) study provided inputs for the power analysis (estimated  $r = -.248$ ) due to its similarity to the current study. Another input, the correlation between two N2pc measures, was estimated as  $r = .50$ , which is a plausible estimate for this within-subject measure in light of no corresponding data in the extant literature. For a medium effect size between the correlations (Cohen's  $q = .3$ ), the study required 93 participants to achieve .80 power at  $\alpha = .05$ . The second power analysis examined the test of a multiple regression interaction effect (G\*Power 3: *linear multiple regression: fixed model,  $R^2$  increase*). Inputs into the power analysis included three predictors (i.e., depression, social anxiety, and their interaction), one tested predictor (i.e., the interaction), and an estimated medium-small effect size ( $f^2 = .085$ , the midpoint between a small [.02] and a medium effect [.15]). To achieve .80 power at  $\alpha = .05$ , this analysis required 95 participants, slightly more than the correlation power analysis. As such, the full sample of participants used in the ANCOVA analyses ( $N = 117$ ) and the samples without outliers used in multiple regressions ( $n = 106$  to  $n = 110$ ) surpassed the required sample size. See Table 1 for participant demographic information and Table 2 for symptom severity statistics. The Results section provides information on data reduction.

**Table 1***Demographic Information*

Variable	<i>N</i> = 117
	<i>M (SD)</i>
Age (years)*	20.68 (5.04)
	<i>n (%)</i>
Gender	
Female	82 (70.1%)
Male	33 (28.2%)
Transgender	2 (1.7%)
Race	
White	60 (51.3%)
Multiracial	29 (24.8%)
Black	10 (8.5%)
Latinx	9 (7.7%)
East Asian	6 (5.1%)
South Asian	3 (2.6%)
Class	
Freshman	64 (54.7%)
Sophomore	23 (19.7%)
Junior	15 (12.8%)
Senior	15 (12.8%)

\**n* = 116

**Table 2***Depression and Social Anxiety Descriptive Statistics*

Variable	
	<i>Mean (SD)*</i>
PHQ-9	8.02 (5.68)
SIAS-6	5.79 (5.08)
	<i>n (%)</i>
PHQ-9 $\geq 10$	47 (40.1%)
SIAS-6 $\geq 7$	44 (37.6%)

\*Full sample ( $N = 117$ )

*Note:* PHQ-9 = Patient Health Questionnaire-9, SIAS-6 = Social Interaction Anxiety Scale-6.

PHQ-9  $\geq 10$  and SIAS-6  $\geq 7$  represent likely clinical cutoff scores for depression and social anxiety, respectively (see Measures section).



## Measures

### *Demographics Questionnaire*

This questionnaire asked 12 questions about demographic factors (e.g., age, race, gender, class standing) in order to fully describe the study sample (see Appendix A).

### *Recent Depression*

The Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) is a nine-item questionnaire that asks participants to rate the frequency at which they experience nine depression symptoms in the previous two weeks (see Appendix A). Participants respond to items (e.g., *Little interest or pleasure in doing things* and *Feeling down, depressed, or hopeless*) using a 4-point Likert scale (0 = *Not at all*, 1 = *Several days*, 2 = *More than half the days*, and 3 = *Nearly every day*; see Appendix A). Scores on the PHQ-9 range from 0 to 27 and higher scores indicate greater depression severity. The items were designed to reflect the *Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV)* criteria for MDD, and it remains consistent with the more recent *DSM-5* (APA, 2013; Uher et al., 2014). A score  $\geq 10$  typically has the optimal sensitivity (74% to 88%) and specificity (85% to 91%) for an MDD diagnosis across adulthood (Arroll et al., 2010; Kroenke et al., 2001; Levis et al., 2019). Construct validity has been demonstrated in U.S. college student samples, such that the PHQ-9 strongly correlated with other depression-related measures (Keum et al., 2018; McCord & Provost, 2020) and negatively correlated with mental well-being (Keum et al., 2018). In their college sample, Kuem and colleagues (2018) found that the one-factor model and various two-factor models (cognitive-affective vs. somatic) all adequately fit the data and were invariant across gender and racial groups. The one-factor model of the PHQ-9 is typically the best fit in adult samples (e.g., Huang et al., 2006; Kocalevent et al., 2013; Ryan et al., 2013; for a review, see Lamela et al., 2020).

The PHQ-9 has demonstrated good internal consistency in the general population (Cronbach's  $\alpha = .79$  to  $.89$ ; Huan et al., 2006; Kocalevent et al., 2013; Martin et al., 2006) and across gender and racial groups in a U.S. college student sample (Cronbach's  $\alpha = .86$  to  $.93$ ; Keum et al., 2018). In the current sample, internal consistency was good (Cronbach's  $\alpha = .86$ ).

### ***Recent Social Anxiety***

The Social Interaction Anxiety Scale-6 (SIAS-6; Peters et al., 2012) is a six-item version of the full 19-item SIAS (Mattick & Clarke, 1998; see Appendix A). The SIAS-6 presents statements about experiencing general distress while interacting with people (e.g., *I have difficulty making eye contact with others* and *I have difficulty talking with other people*). Participants rate how characteristic each statement is of them on a 5-point Likert scale (0 = *Not at all characteristic or true of me* to 4 = *Extremely characteristic or true of me*, see Appendix A). Scores on the SIAS-6 range from 0 to 24 and higher scores indicate more social interaction anxiety. A score  $\geq 7$  on the SIAS-6 achieves optimal sensitivity (85%) and specificity (98%) for an SAD diagnosis (Peters et al., 2012). The SIAS-6 is highly correlated with the full SIAS in college students ( $r = .89$ ; Peters et al., 2012) and has been shown to have equivalent accuracy (i.e., means scores) and precision (i.e., standard errors) as the full SIAS (Sunderland et al., 2020). The six SIAS-6 items were selected from the full scale using item response modeling, such that these items best discriminated the underlying dimension of social interaction anxiety (Peters et al., 2012). The psychometric properties of the SIAS-6 are equivalent or superior to other short versions of the SIAS (Carelton et al., 2014; Le Blanc et al., 2014) and superior to other social anxiety self-report questionnaires (Modini et al., 2015). Convergent validity has been found with other measures of social anxiety and of fear of evaluation (Le Blanc et al., 2014), including in college students (Carelton et al., 2014; Peters et al., 2012). The SIAS-6 has a one-factor structure

in U.S. college student samples (Carelton et al., 2014; Fergus et al., 2014) as well as other samples (e.g., Ouyang et al., 2019; Peters et al., 2012). Internal consistency is typically good in U.S. college students (Cronbach's  $\alpha = .80$  to  $.84$ ; Carelton et al., 2014; Taylor et al., 2019). In the current sample, internal consistency was good (Cronbach's  $\alpha = .85$ ).

### ***Lifetime Depression***

The presence of a lifetime history of major depressive episodes (MDE), which are often episodic (Hardeveld et al., 2010), was assessed for use as a covariate in Hypotheses 1a, 1b, and 3a. Reaction time and eye tracking tasks with longer stimulus durations have found greater attentional bias in people with remitted depression when compared with control participants (Li et al., 2016; Zvielli et al., 2016) and participants with current MDD (Elgersma et al., 2018). In contrast, when examining early attention, bias tends to be reduced in those with remitted MDD (Elgersma et al., 2018; Elgersma et al., 2019; Li et al., 2016). However, the impact of remitted depression on attentional bias has not been tested with the N2pc. In the current study, history of MDE was assessed with the four-item Brief Screening Scale of Lifetime Major Depressive Episode (LMDE; Hitsman et al., 2011; see Appendix A). Participants responded either *Yes* or *No* to questions about a history of depressed mood (item 1), history of anhedonia (item 2 if item 1 is *Yes*, item 3 if item 1 is *No*), and, if *Yes* to any previous item, whether the symptom(s) persisted most of the day nearly every day for at least two weeks (item 4). A positive screen was indicated by a response of *Yes* to item 4. The four items on the LMDE were taken directly from the depression module of the Composite International Diagnostic Interview (CIDI; Kessler et al., 1998), a structured interview that has been validated for use by lay interviewers (Haro et al., 2006). Hitsman and colleagues (2011) tested the acceptability of these four CIDI items as a self-report measure in 1,522 adults who reported a lifetime history of MDE as assessed by the CIDI.

They found the self-report LMDE achieved a positive predictive value of 84.8%, indicating good agreement with the CIDI in this short measure (Hitsman et al., 2011).

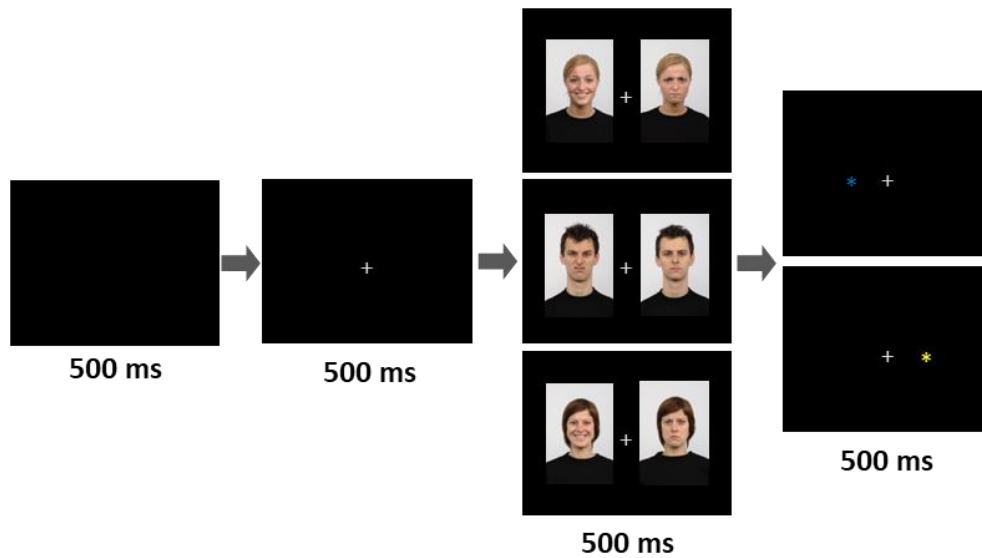
### **Task Stimuli**

The stimuli for the dot-probe task were from the Radboud Face Database (Langer et al., 2010), which contains a set of facial stimuli that were developed for use in research. The study task used photos of the 39 White adult models in the forward-facing position and with frontal eye gaze. The photos captured various facial expressions, each modeled after prototypes in the Facial Action Coding System (Ekman et al., 2002). These images were originally validated in undergraduate students, who judged the target emotion and rated each face on the intensity, clarity, and genuineness of the expression as well as attractiveness (Langer et al., 2010). The current study used photos exhibiting happy, sad, angry, disgust, and neutral facial expressions. Sad and happy faces targeted depression-related attentional biases, in line with cognitive theories of depression (Disner et al., 2011; LeMoult & Gotlib, 2019) and dot-probe studies on depression (e.g., Mogg et al., 2000; Joorman & Gotlib, 2007). Angry and disgust faces align with the social threat attentional biases expected by cognitive theories of social anxiety (Clark & Wells, 1995; Heimberg et al., 2010) and with dot-probe studies on social anxiety (e.g., Reutter et al., 2017; Yuan et al., 2020; for a review, see Bantini et al., 2016).

### **Dot-probe Task**

Prior to the dot-probe task (see Figure 2), participants saw the following instructions: “For the following computer task, press the 'z' key whenever you see a yellow "\*" and the 'm' key if you see a blue "\*". Focus on the fixation symbol in the center of the screen at all times. Please respond as quickly and accurately as possible.” The specific key pressed for each color was counterbalanced, such that for half of the participants the ‘z’ key corresponded to a blue asterisk

and the ‘m’ key corresponded to a yellow asterisk. Participants completed nine practice trials that were identical to the study trials except that the practice trials used red and green rectangles instead of face stimuli and provided feedback (i.e., “Correct!” for a correct probe response, “Oops! That was wrong” for an incorrect probe response, or “Please respond faster” after 2000 ms of no response). Each trial began with a blank, black screen for 500 ms. Then, a white fixation cross (+) appeared in the center of the screen and remained on the screen for the remainder of the trial. After 500 ms, a pair of two faces were randomly selected to appear on the screen, with one face on each side of the screen such that they were equidistant from the fixation cross. The faces remained on the screen for 500 ms, after which a probe (\*) appeared centered in the spatial location of one of the faces. The probe was randomly presented in either blue or yellow color and remained on the screen for 500 ms or until the participant responded. After offset of the probe, the fixation cross remained alone on the screen for one additional frame (16.7 ms) on a random 75% of trials in order to randomize the length of the interval between each trial. In line with a previous study that found an effect of social anxiety on the N2pc, at least 250 trials were expected to be needed for each condition, including trials that would get excluded during EEG artifact rejection (Judah et al., 2016). So that each facial expression could be paired equally with the other four expressions (64 trials for each pairing) 256 trials were required for each facial expression. Given the five facial expressions, there were a total of 1,280 trials. There were 20 second breaks after every 80 trials, for a total of seven breaks.

**Figure 2***Dot-probe Task*

*Note.* The sequence of one trial of the dot-probe task. In the figure, face pictures are enlarged to show detail and represent possible combinations of facial expressions (right-to-left, top-to-bottom: happy, angry, disgust, neutral, happy, sad). The probe screens represent two possible combinations of probe color and side (top-to-bottom: blue left probe, yellow right probe). Following offset of the probe, the fixation cross remained on the screen for an additional frame (16.7 ms) on a random 75% of trials.

## **Procedure**

This study obtained approval from the ODU Institutional Review Board (reference number: 20-152). Participants provided informed consent prior to completing any study procedures, spent approximately three hours in the lab, and received research credit (3.5 points) for participating. After consenting, they completed the demographic, PHQ-9, SIAS-6, and LMDE questionnaires on a computer, along with other questionnaires for concurrent studies (total questionnaire time = 20-30 minutes). Researchers then fit an electrode cap on the head of the participants and attached EEG, electrooculography (EOG), and electrocardiography (ECG) electrodes to measure electrocortical, ocular, and cardiac activity, respectively. Participants were positioned approximately 70 cm from a high-definition Dell computer monitor (refresh rate = 60 Hz), with a keyboard situated in front of them. The dot-probe task was built and presented using PsychoPy software (version 2; Peirce, 2009) and the stimuli were synched to the monitor refresh rate to facilitate precise timing. Participants read the task instructions and had the opportunity to ask questions before proceeding to the practice trials and study trials. The task took approximately 30 minutes to complete. At the conclusion of the study, researchers debriefed participants about the study and removed the electrodes.

## **EEG Data Collection and Processing**

EEG data were sampled at 1024 Hz on an ActiveTwo BioSemi system with 33 active scalp electrodes, and data were later down sampled to 256 Hz. EEG electrodes were placed using an electrode cap that follows the international 20-10 system of electrode placement (Sazgar & Young, 2019). EOG electrodes were placed around participants' eyes to measure eye blinks and ECG electrodes followed a modified Lead II placement with an electrode on the lower left rib cage and above the right collarbone (Stern, Ray, & Quigley, 2001). Data were processed in

MATLAB using EEGLAB (version 14; Delorme & Makeig, 2004) and ERPLAB (version 8.0; Lopez-Calderon & Luck, 2014). Consistent with similar studies, the data were filtered with a 0.1 Hz high pass filter and the scalp electrodes were referenced to the average of the two mastoid electrodes (Judah et al., 2016; Kappenman et al., 2014). Data were segmented into epochs from 200 ms prior to face pair onset to 500 ms after face pair onset. Post-stimulus EEG were baseline corrected using the 200 ms prior to the stimulus. Ocular artifacts (e.g., from eye blinks) were corrected using independent component analysis (Makeig et al., 1996) and trials with artifacts occurring prior to the end of the N2pc time window were rejected. Data from electrodes not used in analyses were interpolated if visual inspection indicated poor recording at any such electrode and a maximum of one of the six electrodes of interest was interpolated for each participant if needed. Automated artifact rejection routines identified trials with other artifacts (e.g., extreme voltages, rapid changes in voltage). Visual inspection verified optimal performance of artifact detection. Rejection of more than 30% of trials in a single face condition resulted in exclusion of that participant's data from analyses.

## **N2pc**

The N2pc, the primary outcome variable, was measured at the occipito-parietal electrodes (P3/4, PO3/4, and O1/2) in the 200 ms to 300 ms time window after the onset of the face pairs (Judah et al., 2016). The average ERP amplitudes (in  $\mu\text{V}$ ) of the pooled ipsilateral electrodes (e.g., P3, PO3, and O1) was subtracted from pooled contralateral electrodes (e.g., P4, PO4, and P2) to compute the N2pc (i.e.,  $\mu\text{V}_{\text{contra}} - \mu\text{V}_{\text{ipsi}}$ ). Ipsilateral and contralateral were defined as, respectively, the same or opposite hemisphere relative to the visual hemifield containing the facial expression of interest. Thus, each of the five N2pc variables were composed of the averaged ERP from occipito-parietal electrodes opposite the face of interest (e.g., sad faces)



compared to occipito-parietal electrodes on the same side as the face of interest (e.g., opposite the happy, angry, disgust, and neutral faces when they were paired with sad faces). The five N2pc face variables were denoted as N2pc-happy, N2pc-sad, N2pc-angry, N2pc-disgust, and N2pc-neutral. Operationally, each N2pc variable represented the extent of preferential orienting of attention toward or away from a specific face when paired with any of the other facial expressions. As the N2pc is a negative-going ERP, a negative N2pc indicates attentional bias toward the face of interest, while a positive N2pc indicates attentional bias away from the face of interest and toward the combination of the faces paired with the face of interest.<sup>2</sup>

### **Reaction Time**

Reaction time (RT), the secondary outcome variable, was measured as the latency in milliseconds of the participants' button press responses to the color of the probe in the dot-probe task. Average reaction times were calculated across for congruent trials and incongruent trials for each facial expression. Congruent trials were defined as those on which the probe appeared on the same side as the face of interest, while incongruent trials were those on which the probe appeared opposite the face of interest. The average reaction time on incongruent trials was subtracted from the average reaction time on congruent trials, such that a negative reaction time score represented attentional bias toward the face of interest (as with the N2pc). The five RT face variables were denoted as RT-happy, RT-sad, RT-angry, RT-disgust, and RT-neutral. To limit the impact of guessing and random responding, only trials with correct responses and RTs within an expected time frame (i.e., not less than 150 ms or more than 2.5 *SD* above the median within

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<sup>2</sup> The attentional bias for each face were not compared with that of one specific face in this study. We were unable to make these specific comparisons because there would have only been 64 trials of each specific face combination (e.g., happy with sad). This is too few trials for an adequate signal-to-noise ratio, and the task would be prohibitively long if it included 256 trials for each face combination.

each condition [range: 750-800 ms]) were used in the average (e.g., Evans et al., 2018; Reutter et al., 2017; Yuan et al., 2020).

## **Research Questions and Hypotheses**

### ***Research Question 1***

The first research question was whether depression would be associated with attentional biases for facial expressions theoretically linked to depression when competing for attention with a variety of other facial expressions.

**Hypothesis 1a.** Depression will be associated with greater attentional bias toward sad faces than toward other faces, as indicated by a stronger negative association with N2pc-sad and RT-sad than the bias scores of other faces.

**Hypothesis 1b.** Depression will be associated with less attentional bias toward happy faces than toward other faces, as indicated by a less negative association with N2pc-happy and RT-happy than the bias scores of other faces.

### ***Research Question 2***

The second research question was whether social anxiety would be associated with attentional biases for facial expressions theoretically linked to social anxiety when competing for attention with a variety of other facial expressions.

**Hypothesis 2a.** Social anxiety will be associated with greater attentional bias toward disgust faces than toward happy, sad, and neutral faces, as indicated by a stronger negative association with N2pc-disgust and RT-disgust than the bias scores of other faces.

**Hypothesis 2b.** Social anxiety will be associated with greater attentional bias toward angry faces than toward happy, sad, and neutral faces, as indicated by a stronger negative association with N2pc-angry and RT-angry than the bias scores of other faces.

### ***Research Question 3***

The third research question was whether co-occurring depression and social anxiety symptoms would influence attentional biases for facial expressions theoretically linked to either MDD or SAD.

**Hypothesis 3a.** The associations between depression and attentional bias toward sad faces (i.e., a more negative N2pc-sad and RT-sad) and away from happy faces (i.e., a more positive N2pc-happy and RT-happy) will remain across levels of social anxiety, but these attentional biases will reduce at increasing levels of social anxiety.

**Hypothesis 3b.** The associations between social anxiety and attentional bias toward disgust and angry faces (i.e., a more negative N2pc-disgust, N2pc-angry, RT-disgust, and RT-angry) will remain across levels of depression, but these attentional biases will reduce at increasing levels of depression.

### **Analyses**

Several social anxiety N2pc studies have divided participants into low and high symptom level groups based on data-driven or arbitrary cutoffs of continuous measures (Judah et al., 2016; Wieser et al., 2018; Yuan et al., 2020). In contrast, the present analyses maintained the continuous nature of the self-reported symptom questionnaires, as in Reutter and colleagues' (2017) study in which the main outcome variable was a correlation between self-reported social anxiety symptom severity and the N2pc response to angry faces. Although the current study proposed correlation analyses, additional analyses were needed to best fit the study design (i.e., having more than one type of emotional face) and the hypotheses related to comparing biases across the faces. Given the increased potential for Type I error from comparing many faces to each other, the analyses began with an omnibus test of whether differences exist between the

faces. For this, a one-way repeated measures analysis of covariance (ANCOVA) was used, with a face factor (five levels) predicting the N2pc or RT and with symptom severity (either depression or social anxiety) as a covariate. In accordance with hypotheses 1 and 2, a significant interaction between face and symptom severity was expected. This interaction would indicate that symptom severity was related to the N2pc or RT differently across the five face levels and it would be followed up within each level, which is necessary when the covariate is of main interest (Engqvist, 2004). The planned follow-up tests involved comparing the bivariate Pearson correlations between symptom severity and the N2pc or RT for each face. The comparisons between correlations were designed to employ Wilcox's (2009) approach (see also Wilcox, 2022). This approach follows Zou's (2007) method for comparing dependent overlapping correlations (i.e., two correlations with one variable in common) and account for the correlation between the two non-overlapping variables (two N2pc variables in the current study; for the formula, see Wilcox, 2009, p. 7). However, unlike Zou (2007), Wilcox's (2009) approach constructs confidence intervals (CIs) using bootstrap resampling and employs the HC4 method for estimating heteroscedastic-consistent standard errors (Cribari-Neto, 2004). HC4 is robust to heteroscedastic and non-normal data for dependent overlapping correlations and thus reduces Type I error (Wilcox, 2009).

More specifically, following the ANCOVA, correlations of depression with N2pc-sad/RT-sad and N2pc-happy/RT-happy were to be compared to the correlations with the other faces and to each other (7 comparisons). These analyses applied to hypotheses 1a and 1b, which predicted that the sad and happy attentional biases would be related to depression more so than other faces. Similarly, the correlations of social anxiety with N2pc-disgust/RT-disgust and N2pc-angry/RT-angry were to be compared to the correlations with the other faces and to each other (7

comparisons), which would test hypotheses 2a and 2b that disgust and angry attentional biases were related to social anxiety more than other faces. Statistical significance for these comparisons were set at  $p < .05$  with the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995) used to control the false discovery rate and reduce Type I error for the multiple comparisons. This correction procedure, which is appropriate for ERP data (Groppe et al., 2011), was selected to increase power by adjusting  $p$ -values according to their rank order rather than applying the same correction to all comparisons as in the Bonferroni correction. If the ANCOVA interaction between face and symptom severity were not significant, the main effect of face would be interpreted. Importantly, both the ANCOVA and correlation comparisons would take advantage of relations between the repeated measures, thus increasing power to detect effects. The ANCOVA was conducted in IBM SPSS (version 27), while comparison of bootstrapped correlations were proposed for analyses in R using Wilcox's (2009) *TWOvov*.

Hypotheses 3a and 3b were examined using four hierarchical multiple linear regressions, one for each emotional facial expression. In each regression, the dependent variable was the attentional bias (either N2pc or RT) for a particular face. The first step in the regressions included depression severity and social anxiety severity (both centered) as predictors. This step quantified the variance in the N2pc or RT that was uniquely attributed to depression and social anxiety. Step two added in the interaction of depression and social anxiety, which tested whether the N2pc or RT response changes at varying levels of co-occurring depression and social anxiety. Thus, hierarchical regressions were designed to inform the depression and social anxiety literatures of the unique effects of each syndrome as well as provide information about the effect of co-occurring depression and social anxiety. The regression analyses were conducted using the *PROCESS* macro for R (version 4.1; Hayes, 2017) and included follow-up evaluation of

moderator values that were identified with the Johnson-Neyman technique. To visual the effects of significant N2pc interactions, the Johnson-Neyman technique also identified meaningful moderator values at which to divide the sample. Accordingly, the moderator value for N2pc-Sad ( $\text{SIAS-6} \leq 3$ ) was selected based on the SIAS-6 score below which the N2pc-Sad effect was significant. The moderator value for N2pc-Angry ( $\text{PHQ-9} \leq 9$ ) was selected based on the PHQ-9 score at which the N2pc-Angry effect changed from positive to negative.

Prior to analyses, the questionnaire data were examined for patterns of missingness to determine any patterns of missingness. Assumptions of the statistical analyses were examined. The assumptions of one-way repeated measures ANCOVA include sphericity of the variance of the residuals, no significant outliers, normally distributed residuals of the dependent variable at each level of the within-subject variable, and homoscedasticity of residuals. Mauchly's test examined sphericity and Greenhouse-Geiser correction was applied if the assumption was violated. Outliers were examined at each level of the within-subjects factor using boxplots, such that values 1.5 interquartile ranges below quartile one or above quartile three will be considered for outliers. Multivariate outliers were evaluated by detecting extreme values of discrepancy (studentized deleted residuals), distance (Mahalanobis), and influence (standardized DfFit [DFFITS] and Cook's D). Outliers were winsorized and data were analyzed before and after winsorizing to observe the outliers' impact on significance and effect sizes. Normality of residuals were violated if 1) the unstandardized residuals were not in a straight line on the Q-Q plots at each level of the within-subjects variable, or 2) the Shapiro-Wilk test was significant. ANCOVA is robust to non-normal distributions at this sample size, but serious violations of normality were adjusted using data transformations. Homoscedasticity were examined by plotting the unstandardized residuals against the independent variable in a scatterplot and

visually examining the consistency of vertical spread. Note that interpreting the within-subject main effect of ANCOVA assumes homogeneity of regression slopes across the levels of the within-subjects factor (i.e., no interaction), but the interaction can still be interpreted and followed-up (Engqvist, 2004; Schneider et al., 2015).

Pearson correlations assume linearity, homoscedasticity of residuals, normality of residuals, and no significant outliers. Linearity was evaluated by plotting the residuals against each variable and examining the lowess line, which should be horizontal and at zero. These scatterplots were also examined for the assumption of homoscedasticity by evaluating the consistency of the vertical spread. The assumption of normality was violated if the unstandardized residuals were not in a straight line on the Q-Q plot. While the degree of non-normality and heteroscedasticity was examined, Wilcox's (2009) correlation method is robust to such violations. Univariate and multivariate outliers were already assessed for the ANCOVA. Analyses were conducted with and without multivariate outliers to examine their effects.

Assumptions of multiple regression include linearity, homoscedasticity of residuals, normality of residuals, independence of residuals, no significant outliers, and lack of multicollinearity. Linearity between each independent variable and the dependent variable were evaluated in context of the correlation analyses. Homoscedasticity was assessed by visually evaluating the vertical spread of the unstandardized residuals when plotted against each independent variable. As with the correlations, normality was checked using a Q-Q plot of the unstandardized residuals. Violations of homoscedasticity and normality were addressed through data transformations or, if needed, percentile bootstrapping with heteroscedastic-consistent standard errors using the PROCESS macro for R (version 4.1; Hayes, 2017). Independence of residuals was checked by examining clustering (using a lowess line in a scatterplot of the

residuals against cases), serial dependency (using the Durbin-Watson test), and autocorrelations. Multivariate outliers were assessed as done in the correlations analyses and analyses were conducted with and without outliers to examine their effects. Multicollinearity of the independent variables was assessed by evaluating tolerance, which should approximate 1.0 and be greater than 0.1.



## CHAPTER III

### RESULTS

#### Data Reduction

The emotional dot-probe task was completed by 161 participants. Six participants were excluded due to errors in saving data and 12 were excluded for not meeting the threshold number of valid RT trials. One participant was excluded for observations of poor effort on the task and 25 participants were excluded for not meeting the threshold number of valid N2pc trials. Thus, 117 participants remained for data analysis.

#### Statistical Assumptions

There were no missing questionnaire data.

#### *N2pc*

For the ANCOVA with depression, Mauchly's test of sphericity was not significant ( $\chi^2(9) = 11.19, p = .26$ ). Non-normality of residuals was detected for N2pc-Angry, N2pc-Sad, and N2pc-Happy using Q-Q plots and Shapiro-Wilk tests ( $Ws(117) < .98, ps < .01$ ). Visual inspection showed some evidence of heteroscedastic residuals across the face types. Data transformations did not improve non-normality or heteroscedasticity. However, after winsorizing 19 univariate and multivariate outliers across all face type variables, residuals achieved approximate normality as indicated by Shapiro-Wilk tests that were no longer significant ( $Ws(117) > .98, ps > .08$ ) and homoscedasticity was improved as seen in visual inspection. The ANCOVA with social anxiety was examined next and showed a non-significant Mauchly's test of sphericity ( $\chi^2(9) = 11.49, p = .24$ ). Non-normality of residuals was detected for N2pc-Angry, N2pc-Sad, and N2pc-Happy using Q-Q plots and Shapiro-Wilk tests ( $Ws(117) < .98, ps < .02$ ). Visual inspection showed some evidence of heteroscedastic residuals across all the face types.

Again, data transformations did not improve non-normality or heteroscedasticity. After winsorizing one SIAS-6 outlier and 19 N2pc outliers across all face types, residuals achieved approximate normality such that Shapiro-Wilk tests were no longer significant ( $Ws(117) > .97$ ,  $ps > .06$ ) and homoscedasticity was improved as indicated by visual inspection. Analyses were conducted with winsorized data and compared to non-winsorized results.

For the multiple regression analyses, the independent variables were centered and there was no evidence of problematic multicollinearity (tolerance = .62 to .76). Q-Q plots and Shapiro-Wilk tests showed residuals were not normally distributed for the regressions predicting N2pc-Angry, N2pc-Sad, or N2pc-Happy ( $Ws(117) < .97$   $ps < .01$ ). Heteroscedasticity was evident in the residual scatter plots across all face types and 7-10 multivariate outliers were identified within each face type. To address non-normal and heteroscedastic residuals, analyses were conducted using percentile bootstrapped confidence intervals and heteroscedastic-consistent standard errors (HC4) in the PROCESS macro. Analyses were conducted with multivariate outliers removed and compared to analyses including the outliers.

### ***Reaction Time***

Mauchly's test of sphericity was not significant for the ANCOVA with depression ( $\chi^2(9) = 9.06$ ,  $p = .43$ ). For the ANCOVA with depression, residuals for each face type were normally distributed, as evinced by the Q-Q plots and non-significant Shapiro-Wilk tests ( $Ws(117) > .98$ ,  $ps > .24$ ). Residual scatter plots showed some evidence of heteroscedasticity. After transforming (natural log) RT and PHQ-9 variables and winsorizing 21 univariate and multivariate outliers across all face type variables, heteroscedasticity was improved as seen in residual scatter plots. The ANCOVA with social anxiety was examined next and showed a non-significant Mauchly's test of sphericity ( $\chi^2(9) = 9.19$ ,  $p = .42$ ). Residuals for each face type were normally distributed,

as evinced by the Q-Q plots and non-significant Shapiro-Wilk tests ( $Ws(117) > .98, ps > .28$ ). Residual scatter plots showed some evidence of heteroscedasticity. After transforming (natural log) RT and SIAS-6 variables, heteroscedasticity was no longer evident in the residual plots. Across all face type variables, 21 univariate and multivariate RT outliers were winsorized. Analyses were conducted with winsorized data and compared to non-winsorized results.

As in the N2pc regressions, the independent variables remained centered and there was no problematic multicollinearity (tolerance = .62 to .76). Q-Q plots and Shapiro-Wilk tests showed residuals for each regression were normally distributed ( $Ws(117) > .98, ps > .22$ ). Heteroscedasticity was evident in the residual scatter plots of RT-Angry, RT-Neutral, and RT-Happy and 7-11 multivariate outliers were identified within each face type. To address heteroscedastic residuals, analyses were conducted using percentile bootstrapped confidence intervals and heteroscedastic-consistent standard errors (HC4) in the PROCESS macro. Analyses were conducted with multivariate outliers removed and compared to analyses including the outliers.

## **N2pc Results**

The ANCOVA modeled to predict N2pc from face type and depression severity showed no significant main effect of face type ( $F(4, 460) = 0.83, p = .51, \eta_p^2 = .007$ ) and no significant interaction between face type and depression ( $F(4, 460) = 0.58, p = .68, \eta_p^2 = .005$ )<sup>3</sup>. Similarly, the ANCOVA predicting N2pc from face type and social anxiety severity showed no significant effect of face type ( $F(4, 460) = 1.28, p = .28, \eta_p^2 = .011$ ) and no significant interaction between

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<sup>3</sup> Lifetime history of major depression was used as a covariate in a subsample that completed the LMDE screener ( $n = 65$ , negative screens = 37, positive screen = 28). The results were not (continue on next page) significantly impacted as there remained no significant main effect of face type ( $F(4, 248) = 1.11, p = .35$ ) or interaction between face type and depression ( $F(4, 248) = 0.27, p = .90$ ). There was also no significant interaction between face type and LMDE ( $F(4, 248) = 0.33, p = .86$ ).

face type and social anxiety ( $F(4, 460) = 0.86, p = .49, \eta_p^2 = .007$ )<sup>4</sup>. Although ANCOVA results were not significant, planned pairwise comparisons were examined as exploratory analyses.

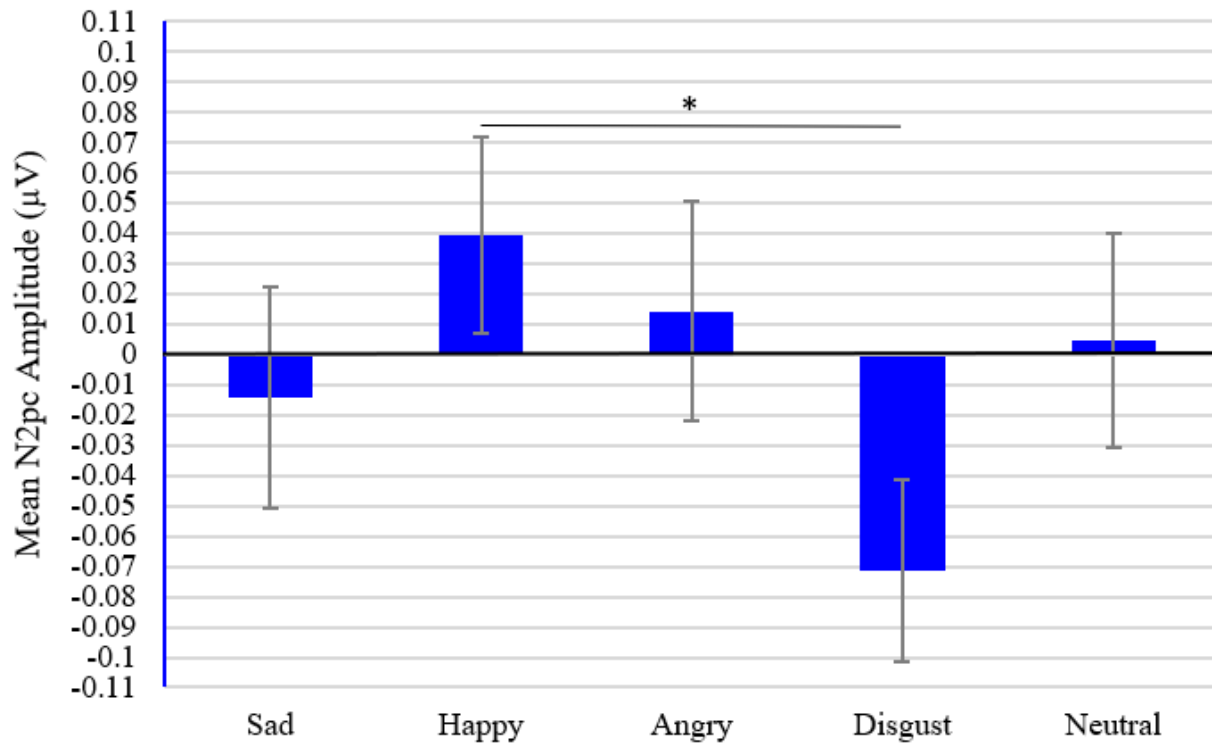
Comparisons between the means of all N2pc face types showed that no single face type stood out as contributing to more attentional bias in general, but N2pc-Disgust ( $M = -0.072$ ) was significantly different from N2pc-Happy ( $M = 0.039, p = .03$ ; see Figure 3). The effect size of this difference was small ( $d_z = .20$ ), which, when compared to a normal distribution, showed that the likelihood of a participant having a more negative N2pc-Disgust than N2pc-Happy was 58.0%.

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<sup>4</sup> Rerunning the ANCOVAs without winsorizing outliers did not change the significance of results. The ANCOVA with depression as a covariate showed no significant main effect of face type ( $F(4, 460) = 0.79, p = .54$ ), and no significant interaction between face type and depression ( $F(4, 460) = 0.48, p = .75$ ). The ANCOVA with social anxiety severity as a covariate showed no significant effect of face type ( $F(4, 460) = 1.45, p = .22$ ) and no significant interaction between face type and social anxiety ( $F(4, 460) = 1.00, p = .43$ ).

**Figure 3**

*Mean N2pc Attentional Bias Scores Across All Participants*

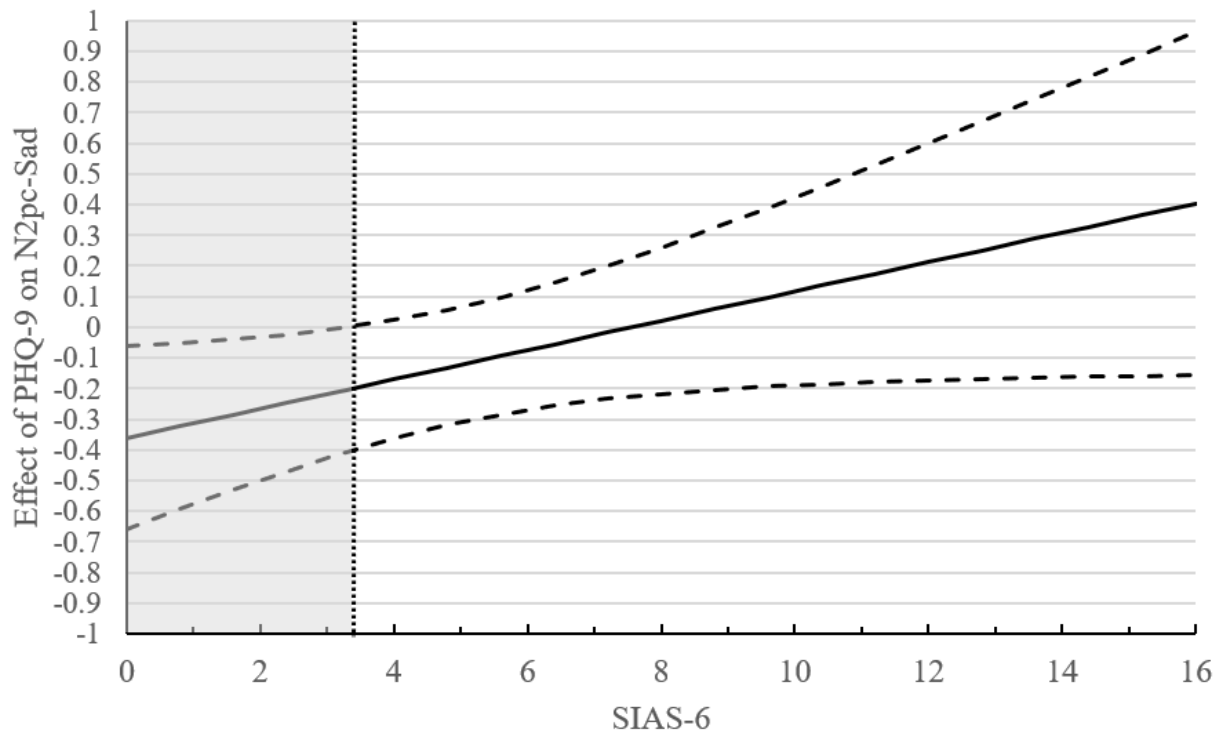


*Note.* The N2pc is the amplitude in microvolts (μV) of the contralateral electrodes minus the ipsilateral electrodes (a more negative N2pc is a bias toward the face of interest).

Multiple regressions predicting N2pc within each face type were examined next. Unstandardized regression coefficients ( $\beta$ 's) and percentile bootstrap 95% CIs are reported. N2pc-Sad was significantly associated with the interaction between depression and social anxiety ( $\beta = 0.004$ , CI [0.0001, 0.0067]), but the main effects of depression ( $\beta = -0.009$ , CI [-0.023, 0.004]) and social anxiety ( $\beta = -0.006$ , CI [-0.023, 0.009]) were not significant. This model accounted for 5.3% ( $R^2 = .053$ ,  $p = .123$ ) of N2pc-Sad, of which the interaction accounted for 2.7% ( $\Delta R^2 = .027$ ,  $p = .049$ ). The Johnson-Neyman test showed that depression was related to a more negative N2pc-Sad only for participants with social anxiety less than .42 *SD* below the mean ( $\text{SIAS-6} \leq 3$ ,  $n = 50$ ), for whom the correlation between depression and N2pc-Sad was  $r = -.28$ ,  $p = .04$  (see Figures 4 and 5). To quantify the interaction effect size, a 2 *SD* change in depression from the Johnson-Neyman results was examined (Bodner, 2017). The semi-partial correlations between depression and N2pc-Sad at -1 *SD* and +1 *SD* of social were  $sr = -.31$  and  $sr = .08$ , respectively, such that 2 *SD* change in social anxiety showed a small-to-medium effect ( $sr_{\text{difference}} = .39$ ; Bodner, 2017).

**Figure 4**

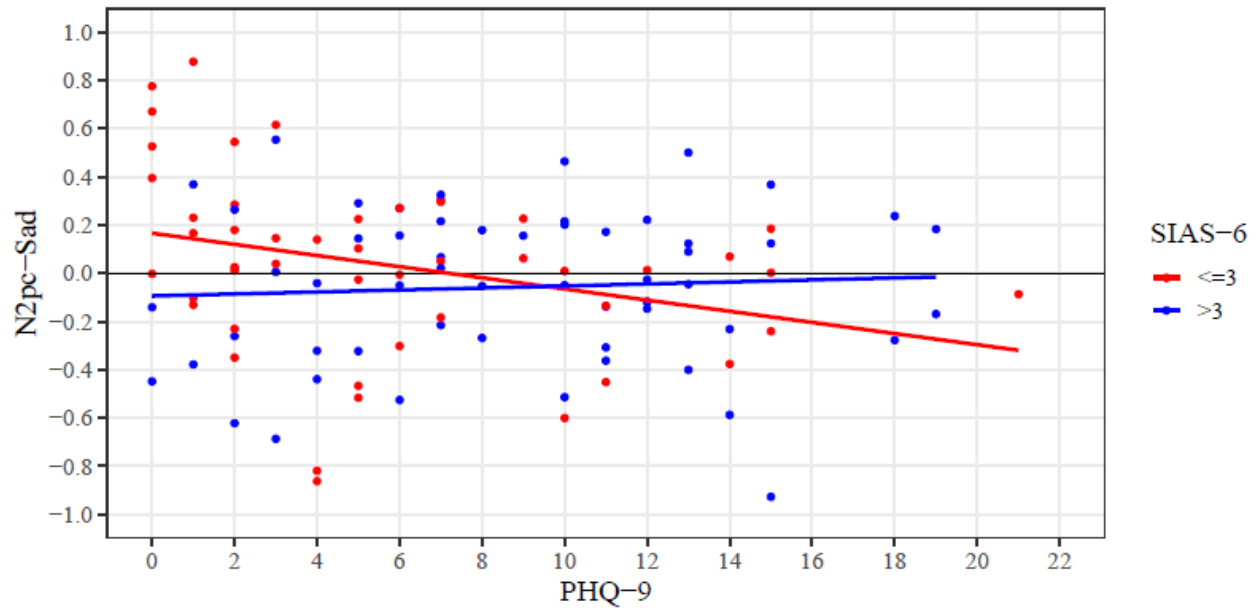
*Johnson-Neyman Plot of the Effect of Depression on N2pc-Sad by Social Anxiety*



*Note.* Effects are standardized coefficients. Dashed lines mark the 95% confidence interval and shaded area marks the zone of significance. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

**Figure 5**

*Association Between Depression and N2pc-Sad by Social Anxiety*



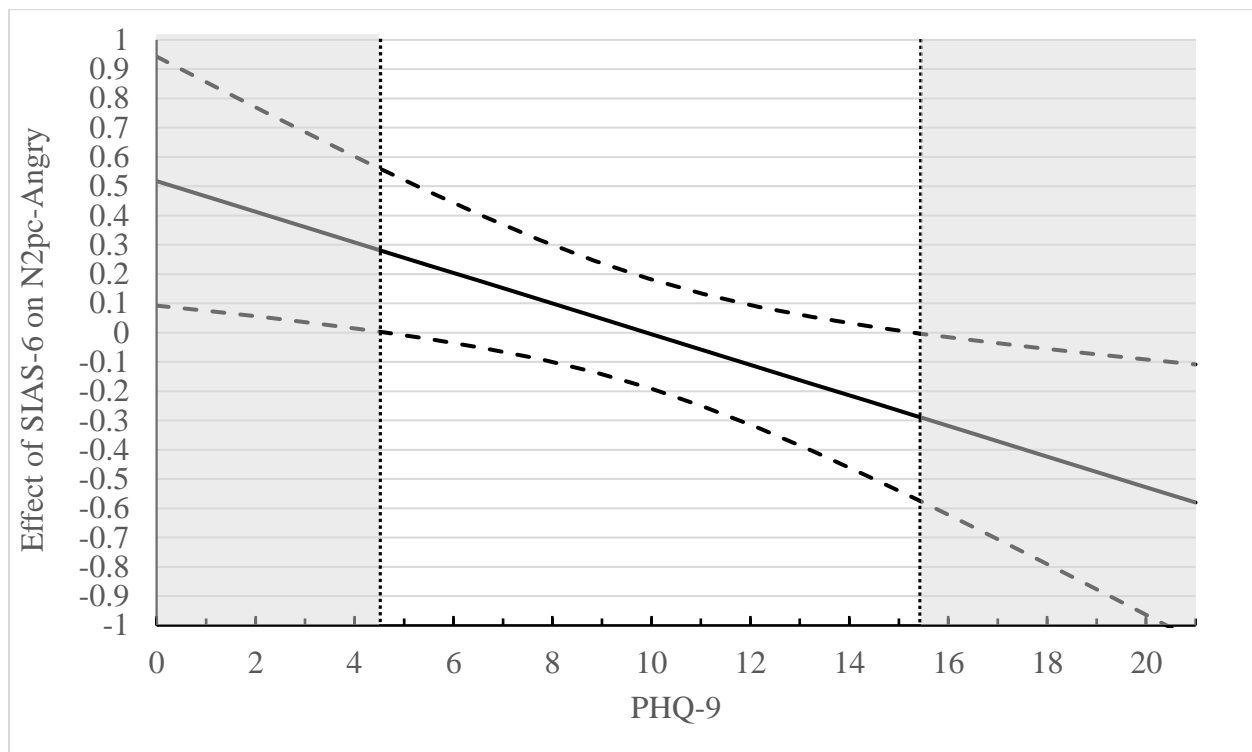
*Note.* Participants grouped by Johnson-Neyman SIAS-6 moderator value. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.



N2pc-Angry was significantly associated with the interaction between depression and social anxiety ( $\beta = -0.004$ , CI [-0.007, -0.001]), but the main effects of depression ( $\beta = 0.003$ , CI [-0.011, 0.017]) and social anxiety ( $\beta = 0.011$ , CI [-0.006, 0.028]) were not significant. This model accounted for 6.2% ( $R^2 = .062$ ,  $p = .036$ ) of N2pc-Angry, of which the interaction accounted for 4.6% ( $\Delta R^2 = .046$ ,  $p = .009$ ). The Johnson-Neyman test showed that social anxiety was significantly related to a more positive N2pc-Angry for participants with depression less than .53 *SD* below the mean ( $n = 35$ ). Social anxiety was marginally related to a more *negative* N2pc-Angry when depression was high, but the effect was only significant when depression was more than 1.61 *SD* above the mean ( $n = 3$ ; see Figure 6). To better see the change in direction of the effect across levels of depression, the Johnson-Neyman results were used to identify the point on depression at which the direction changed (+.53 *SD*). The correlation between social anxiety and N2pc-Angry for participants with depression less than .53 *SD* above the mean ( $n = 68$ ) was  $r = .29$  ( $p = .02$ ), while the correlation among participants with depression above this point ( $n = 39$ ) was  $r = -.27$  ( $p = .10$ ; see Figure 7). The semi-partial correlations between social anxiety and N2pc-Angry at -1 *SD* and +1 *SD* of depression were  $sr = .37$  ( $p = .03$ ) and  $sr = -.12$  ( $p = .24$ ), respectively, such that 2 *SD* change in depression showed a medium effect ( $sr_{\text{difference}} = .48$ ; Bodner, 2017).

**Figure 6**

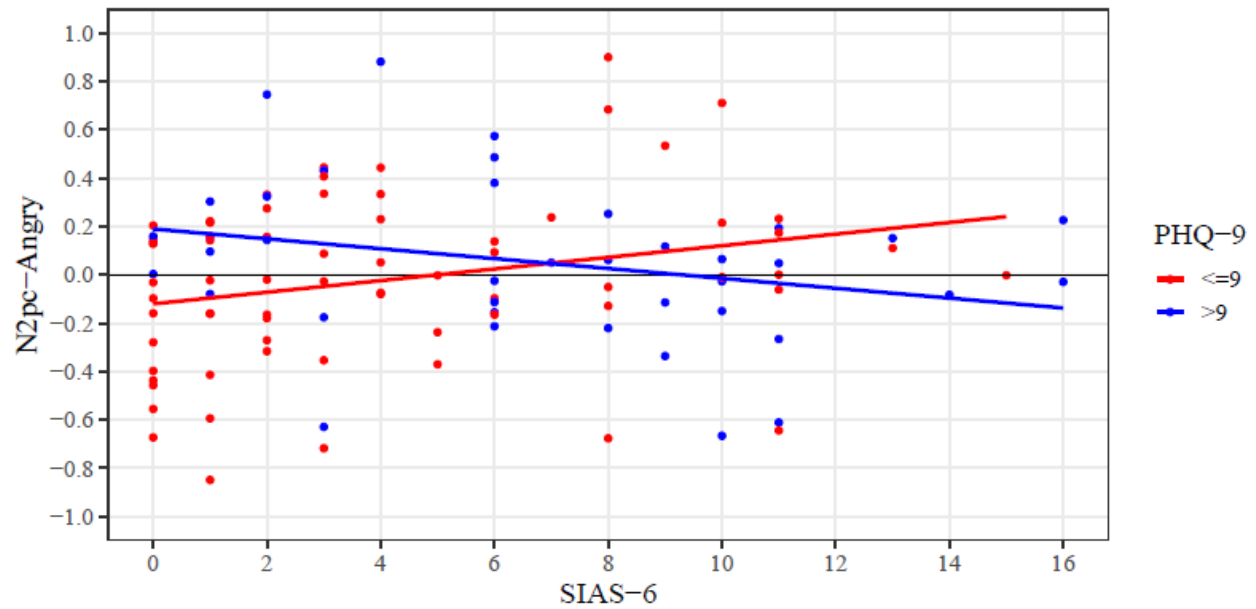
*Johnson-Neyman Plot of the Effect of Social Anxiety on N2pc-Angry by Social Anxiety*



*Note.* Effects are standardized coefficients. Dashed lines mark the 95% confidence interval and shaded areas mark the zones of significance. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

**Figure 7**

*Association Between Social Anxiety and N2pc-Angry by Depression*



*Note.* Participants grouped by the Johnson-Neyman value of transition from a positive to negative effect. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

None of the other N2pc responses were significantly related to symptom severity in the multiple regression analyses. Specifically, there were no significant associations between depression, social anxiety, or their interaction and N2pc-Disgust ( $\beta = 0.008$ , CI [-0.003, 0.020];  $\beta = 0.0002$ , CI [-0.014, 0.015];  $\beta = 0.002$ , CI [-0.001, 0.005], respectively), N2pc-Neutral ( $\beta = 0.002$ , CI [-0.010, 0.016];  $\beta = 0.007$ , CI [-0.009, 0.023];  $\beta = -0.002$ , CI [-0.006, 0.001]), or N2pc-Happy ( $\beta = -0.004$ , CI [-0.016, 0.008];  $\beta = -0.009$ , CI [-0.025, 0.008];  $\beta = -0.001$ , CI [-0.005, 0.002])<sup>5</sup>.

### Reaction Time Results

The ANCOVA modeled to predict RT from face type and depression severity showed no significant main effect of face type ( $F(4, 460) = 0.76$ ,  $p = .55$ ,  $\eta_p^2 = .007$ ) and no interaction between face type and depression ( $F(4, 460) = 1.12$ ,  $p = .35$ ,  $\eta_p^2 = .010$ )<sup>6</sup>. The ANCOVA modeled to predict RT from face type and social anxiety severity showed a marginally significant main effect of face type ( $F(4, 460) = 2.23$ ,  $p = .07$ ,  $\eta_p^2 = .019$ ) and no significant interaction between face type and social anxiety ( $F(4, 460) = 1.71$ ,  $p = .15$ )<sup>7</sup>. Again, despite non-significant ANCOVA results, planned pairwise comparisons were examined as exploratory

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<sup>5</sup> After including outliers in the analysis, the significance of the interaction between depression and anxiety on the N2pc-Sad remained the same ( $\beta = 0.003$ , CI [0.001, 0.005]), as did the non-significant effect of social anxiety ( $\beta = -0.023$ , CI [-0.054, 0.006]). However, the effect of depression on N2pc-sad became significant ( $\beta = -0.024$ , CI [-0.05, -0.006]). The effect of the interaction on N2pc-Angry was changed to being only marginally significant ( $\beta = 0.002$ , CI [-0.004, 0.001]) and the effects of depression and social anxiety remained non-significant ( $\beta = 0.02$ , CI [-0.004, 0.038];  $\beta = -0.03$ , CI [-0.004, 0.060], respectively). All other N2pc attentional biases remained non-significant.

<sup>6</sup> Lifetime history of major depression was used as a covariate in a subsample that completed the LMDE screener ( $n = 65$ , negative screens = 37, positive screen = 28). The results were not significantly impacted as there remained no significant main effect of face type ( $F(4, 248) = 0.25$ ,  $p = .81$ ) and no significant interaction between face type and depression ( $F(4, 248) = 0.51$ ,  $p = .73$ ). There was also no significant interaction between face type and LMDE ( $F(4, 248) = 0.33$ ,  $p = .86$ ).

<sup>7</sup> Rerunning the ANCOVAs without winsorizing outliers did not change the significance of results. The ANCOVA with depression as a covariate showed no significant main effect of face type ( $F(4, 460) = 0.65$ ,  $p = .62$ ) and no interaction between face type and depression ( $F(4, 460) = 0.96$ ,  $p = .43$ ). The ANCOVA with social anxiety severity as a covariate showed no significant main effect of face type ( $F(4, 460) = 1.15$ ,  $p = .33$ ) and no interaction between face type and depression ( $F(4, 460) = 1.00$ ,  $p = .41$ ).

analyses. Comparisons between the means of all RT face types showed that RT-Angry ( $M = -2.4$  ms) was significantly different from RT-Disgust ( $M = 1.3$  ms,  $p = .01$ ) and RT-Happy ( $M = 0.8$  ms,  $p = .02$ ; see Figure 8). These differences had small effect sizes ( $d_z = 0.24$  and  $d_z = 0.21$ , respectively) and indicated that the likelihood of a participant having a more negative RT-Angry than RT-Disgust or RT-Happy was 59.6% and 58.5%, respectively.

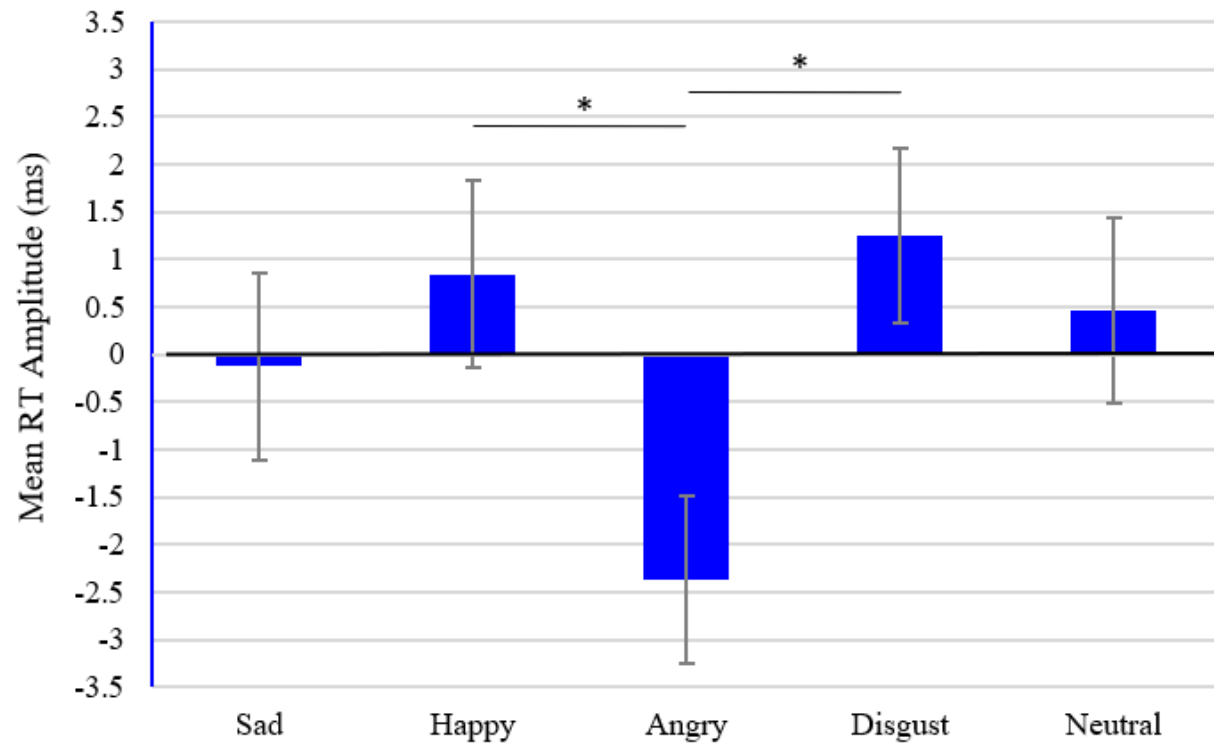
Multiple regressions predicting RT within each face type were examined next. The main effects of depression ( $\beta = 0.12$ , CI [-0.26, 0.51]) and social anxiety ( $\beta = 0.10$ , CI [-0.31, 0.53]) on RT-Disgust were not significant, but their interaction was significant ( $\beta = -0.09$ , CI [-0.19, -.002],  $\Delta R^2 = .028$ ). In total, this model accounted for 3.7% of RT-Disgust ( $R^2 = .037$ ,  $p = .232$ ). The Johnson-Neyman test showed that social anxiety was not significantly related to RT-Disgust at any single level of depression, even though the relation significantly changed from a positive one at low depression to a negative one at high depression (see Figure 9). The semi-partial correlations between social anxiety and RT-Disgust at  $-1$  SD and  $+1$  SD of depression were  $sr = .23$  ( $p = .14$ ) and  $sr = -.14$  ( $p = .24$ ), respectively, such that 2 SD change in depression showed a small-to-medium effect ( $sr_{\text{difference}} = .38$ ; Bodner, 2017)<sup>8</sup>.

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<sup>8</sup> Including outliers in the RT-Disgust multiple regression removed the significant effect of the interaction on RT-Disgust ( $\beta = -0.03$ , CI [-0.09, 0.01]) and the effects of depression and social anxiety remained non-significant ( $\beta = 0.14$ , CI [-0.23, 0.50],  $\beta = 0.30$ , CI [-0.14, 0.77], respectively).

**Figure 8**

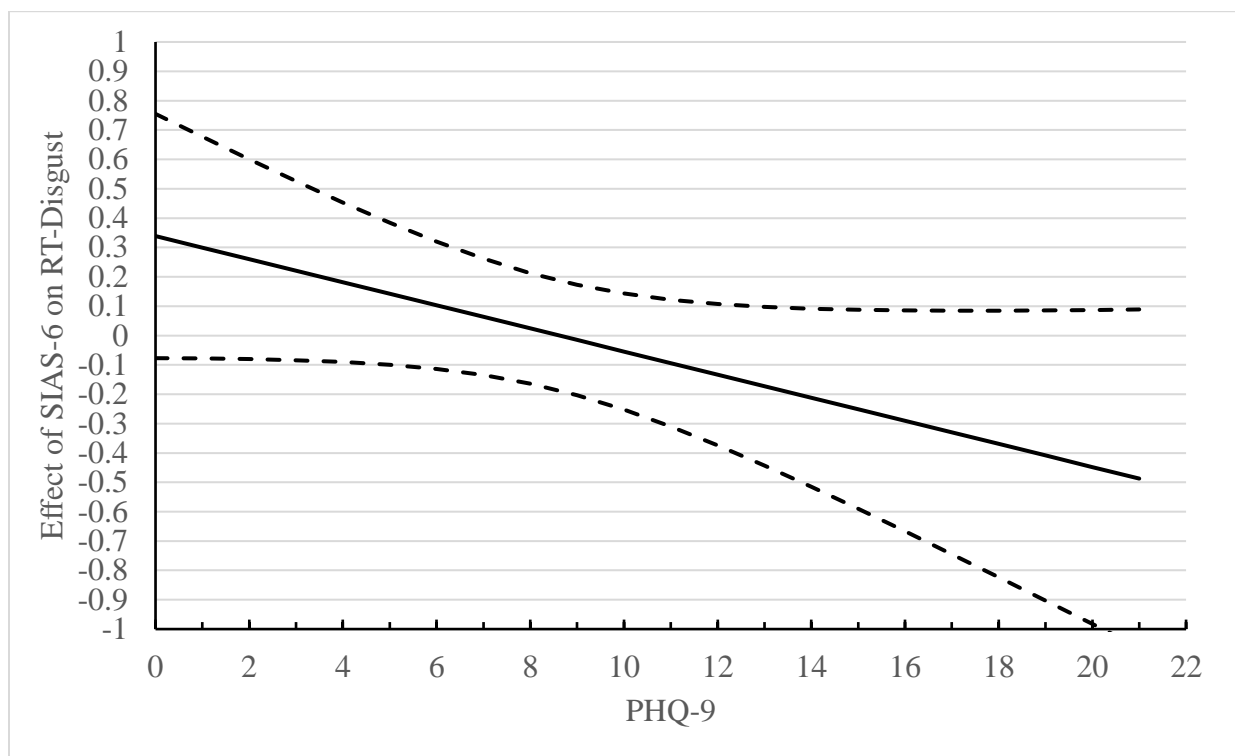
*Mean RT Attentional Bias Scores Across All Participants*



*Note.* Reaction time (RT) is the time in milliseconds (ms) of the congruent trials minus incongruent trials (a more negative RT is a bias toward the face of interest).

**Figure 9**

*Johnson-Neyman Plot of the Effect of Social Anxiety on RT-Disgust by Depression*



*Note.* Effects are standardized coefficients. No zones of significance; see text. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

RT-Neutral was significantly associated with depression ( $\beta = 0.57$ , CI [0.16, 1.00],  $sr = .27$ ) and social anxiety ( $\beta = -0.72$ , CI [-1.17, -0.30],  $sr = -.29$ ), and their interaction ( $\beta = 0.08$ , CI [0.002, 0.17],  $\Delta R^2 = .024$ ). In total, this model accounted for 12.5% of RT-Neutral ( $R^2 = .125$ ,  $p = .002$ ). The Jonson Neyman tests showed that depression was significantly related to bias away from RT-Neutral only for participants with social anxiety above .33 *SD* below the mean ( $n = 61$ ; see Figure 10), while social anxiety was significantly associated with bias toward RT-Neutral only when depression was less than .55 *SD* above the mean ( $n = 75$ ; see Figure 11). The semi-partial correlations between RT- Neutral and depression at -1 *SD* and +1 *SD* of social anxiety were  $sr = .11$  ( $p = .46$ ) and  $sr = .44$  ( $p = .001$ ), respectively, and between RT-Neutral and social anxiety at -1 *SD* and +1 *SD* of depression were  $sr = -.47$  ( $p < .001$ ) and  $sr = -.13$  ( $p = .31$ ), respectively. As such, a 2 *SD* change in one symptom severity scale showed a small effect on these biases ( $sr_{\text{difference}} = .34$ ; Bodner, 2017)<sup>9</sup>.

None of the other RT responses were significantly related to symptom severity in the regression analyses. Specifically, there were no significant associations of depression, social anxiety, or their interaction with RT-Angry ( $\beta = -0.30$ , CI [-0.68, 0.09];  $\beta = 0.22$ , CI [-0.24, 0.63];  $\beta = .03$ , CI [-0.06, 0.13], respectively), RT-Sad ( $\beta = -0.30$ , CI [-0.66, 0.05];  $\beta = -0.18$ , CI [-0.67, 0.31];  $\beta = -0.01$ , CI [-0.09, 0.08]), or RT-Happy ( $\beta = -0.33$ , CI [-0.74, 0.07];  $\beta = -0.12$ , CI [-0.60, 0.36];  $\beta = -0.02$ , CI [-0.12, 0.08]).

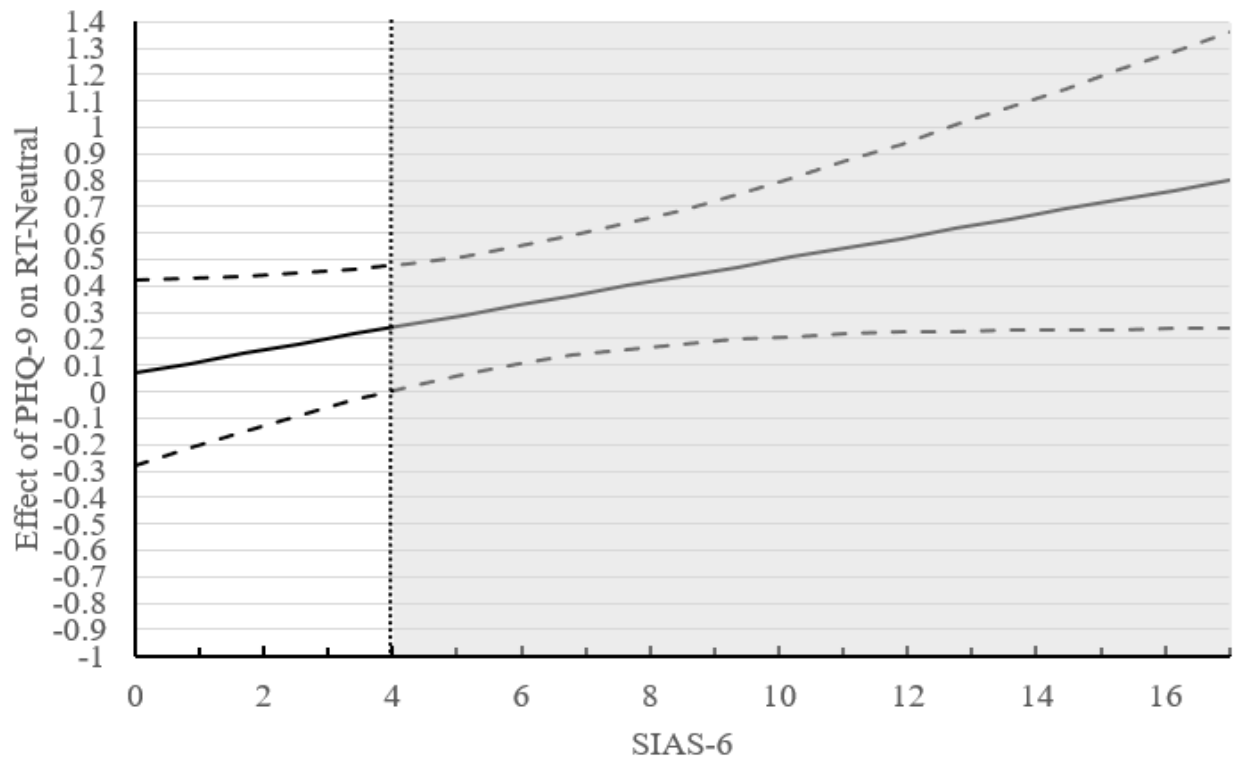
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<sup>9</sup> Including outliers in the RT-Neutral multiple regression removed the significant effects of the interaction on RT-Disgust ( $\beta = -0.01$ , CI [-0.05, 0.10]) as well as the significant effects of depression and social anxiety ( $\beta = 0.09$ , CI [-0.34, 0.60],  $\beta = -0.24$ , CI [-0.77, 0.26], respectively). The RT attentional biases for angry, sad, and happy faces remained non-significant.



**Figure 10**

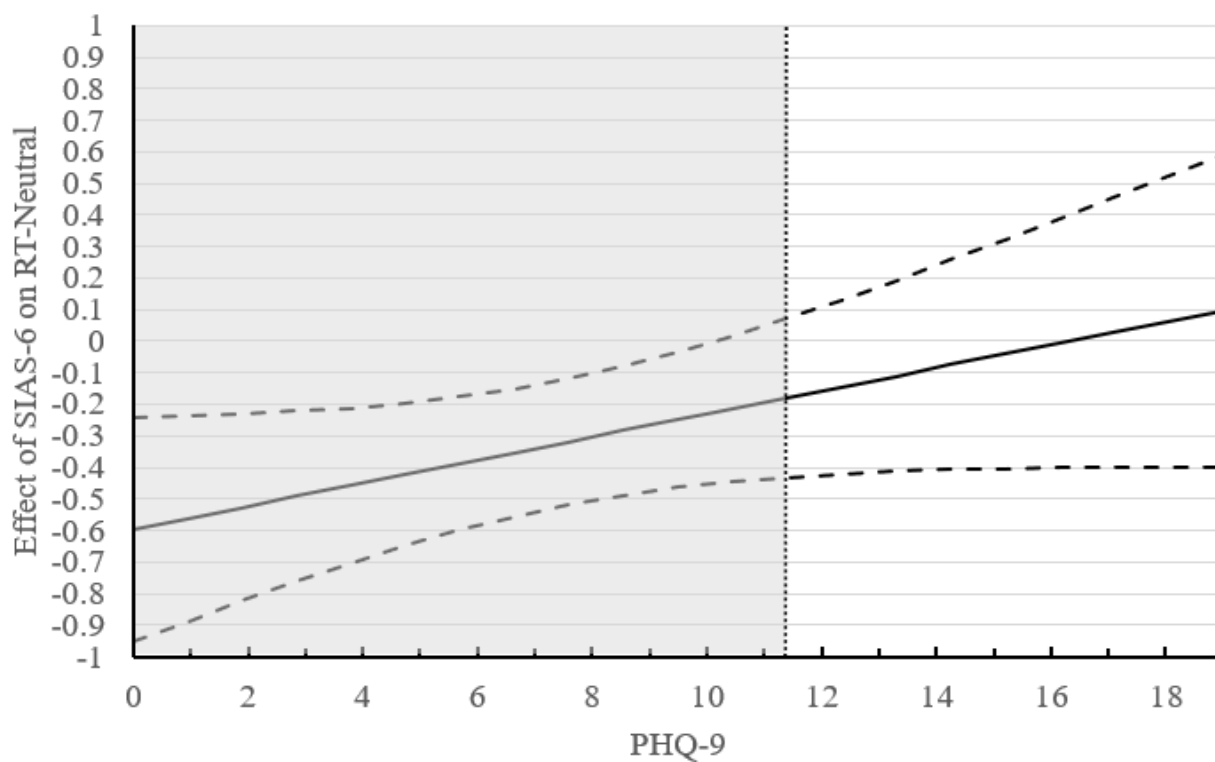
*Johnson-Neyman Plot of the Effect of Depression on RT-Neutral by Social Anxiety*



*Note.* Effects are standardized coefficients. Dashed lines mark the 95% confidence interval and shaded area marks the zone of significance. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

**Figure 11**

*Johnson-Neyman Plot of the Effect of Social Anxiety on RT-Neutral by Depression*



*Note.* Effects are standardized coefficients. Dashed lines mark the 95% confidence interval and shaded area marks the zone of significance. Patient Health Questionnaire-9 = PHQ-9. Social Interaction Anxiety Index-6 = SIAS-6.

## CHAPTER IV

### DISCUSSION

#### Overview of Results

A primary goal of this study was to test which depression and social anxiety-related attentional biases would stand out as stronger than others. Contrary to Hypotheses 1a to 2b, the ANCOVAs did not identify any particular bias as standing out, which was true for both the early neural measure (N2pc) and the later behavioral measure (RT). In particular, depression was not more related to biased attention toward sad faces and away from happy faces than any other face types. Social anxiety was not related to attentional biases toward either disgust or angry faces when compared to other face types, which held true for both the N2pc and RT measures. In addition to these hypothesized comparisons, there were no significant comparisons across any of the five face types in the study (disgust, angry, sad, neutral, and happy). These null results, however, did not rule out the presence of an attentional bias within each face type, which were found in the regression analyses discussed next. The ANCOVAs also showed no main effects of face type on the N2pc or RT, indicating that attention was generally not biased more for any particular face over the others. Despite the null omnibus test of a main effect, exploratory pairwise comparisons of face type did indicate a small effect of the N2pc being biased toward disgust faces, but only when compared to the N2pc response to happy faces. In the exploratory RT pairwise comparisons, a small bias toward angry faces was evident when compared to the RT for disgust and happy faces. Given that no particular face type stood out as more related to depression or social anxiety, the next set of analyses examined whether attentional bias for specific face types would be related to the unique and interacting effects of depression and social anxiety.

Results showed that depression and social anxiety were not uniquely related to the N2pc measure of attentional bias, but their interaction revealed biases related to angry and sad faces. The interaction between depression and social anxiety showed a medium sized effect of social anxiety severity on the relation between depression and N2pc-Sad, such that depression was related to an attentional bias toward sad faces only at low levels of social anxiety. This interaction supported the Hypothesis 3a prediction that the depression-related attentional bias toward sad faces would exist at low social anxiety and be smaller at higher social anxiety, but it was unexpected that the bias would be fully extinguished at high social anxiety. However, in contrast to Hypothesis 3a, the interaction predicting N2pc-Happy was not significant. For the interaction predicting N2pc-Angry, results showed a small-to-medium sized effect of depression severity on the relation between social anxiety and N2pc-Angry, such that social anxiety was related to an attentional bias away from angry faces only at low levels of depression. This attenuated angry bias at higher levels of depression was predicted by Hypothesis 3b, but the direction of the bias—*away from* angry faces—was unexpected. Furthermore, the N2pc-Disgust main effects and interactions predicted in Hypothesis 3b were not significant. Across the N2pc-Angry and N2pc-Sad analyses, the results revealed the common pattern that attentional biases measured by the N2pc were detected only at low levels of depression-social anxiety comorbidity.

In the analyses predicting RT, a hypothesized attentional bias was found in relation to disgust faces and an exploratory analysis of neutral faces revealed additional attentional biases. Although depression and social anxiety did not individually predict RT-Disgust, their interaction was significant and showed a small-to-medium sized effect of depression on the relation between social anxiety and RT-Disgust. Specifically, social anxiety showed a statistically marginal attentional bias *away from* disgust faces at low levels of depression which changed to a

statistically marginal bias *toward* disgust faces at high depression. This interaction partially supported Hypothesis 3b, but the social anxiety attentional bias was unexpectedly *away from* disgust faces at low depression. The interaction was qualified by the attentional bias not being significant at any single point of social anxiety, despite the significant change across levels of depression. The model predicting RT-Neutral had the largest effect of all attentional bias analyses, with 12.5% of RT-Neutral accounted for by depression, social anxiety, and their interaction. Both depression and social anxiety had small-to-medium unique effects on RT-Neutral such that depression was associated with an attentional bias away from neutral faces and social anxiety was associated with a bias toward them. However, the interaction between depression and social anxiety revealed that the effect of depression was only significant for participants with mild to high social anxiety and the effect of social anxiety was only significant for participants with low to mild depression.

### **Comparing Attentional Biases**

The ANCOVA analyses did not provide evidence that depression or social anxiety are related to an attentional bias to one emotion more than the others. These null findings are notable in the context of this study's unique methodological approach of putting emotional faces in direct competition with each other as well as an analytical approach that compared a variety of attentional biases to each other. As the first study to compare attentional biases in this way, it is notable that attentional biases were identified when using the more typical analytic approach in which each bias is examined individually, as discussed in the following sections. Previous depression and social anxiety attentional bias research, particularly regarding the N2pc and other ERPs, has almost exclusively examined attention for emotional stimuli only when compared to neutral stimuli. This study used directly competing emotional stimuli in an attempt to clarify a

largely mixed attentional bias literature. Comparing emotional faces to other emotional faces, rather than just neutral, increased control over the basic effect of emotional arousal on attention and improved ecological validity. Further, any attentional bias detected could be more clearly interpreted as a bias toward/away from a specific emotional face type rather than also as a bias away from/toward neutral faces. Under these stricter conditions and by employing an underutilized and internally valid neural measure of attentional bias, the N2pc, this study sought to improve confidence in the results of attentional bias research.

The null results in the current study suggest that previously reported attentional biases in depression and social anxiety may have confounded bias related to emotional valence with bias related to emotional arousal. It is further possible that the signal-to-noise ratio in the current study was reduced by having more variety in the types of images present to participants. Indeed, attentional biases are known to vary based on task design (e.g., Peckham et al., 2010; Rossignol, Fisch, et al., 2013). The lack of attentional biases toward specific emotional faces stands in most stark contrast with the previous N2pc studies that found social anxiety-related attentional biases toward socially threatening faces (e.g., angry or disgust faces; Judah et al., 2016; Reutter et al., 2017; Wieser et al., 2018; Yuan et al., 2020; Yuan et al., 2021) and the single N2pc study that show a depression-related bias away from sad faces (Gibb et al., 2016). The current study suggests these previously reported biases are not as strong in the presence of competing emotional faces. However, the null findings in this study are consistent with some previous research. First, this study agrees with the many non-N2pc studies that found no or mixed evidence for depression and social anxiety early attentional biases (e.g., Bistricky et al., 2014; Gotlib, Kasch, et al., 2004; Hagemann et al., 2016; Kolassa et al., 2007; Yu et al., 2017). Second, these findings align with studies that showed attention for people with depression and social

anxiety may be biased for emotional faces regardless of the type of emotion (e.g., Byrow et al., 2016; Rossignol, Campanella, et al., 2013; Ruuhonen et al., 2019; Wieser et al., 2009) or both emotional and neutral faces for people with social anxiety (e.g., Hagemann et al., 2016; Helfinstein et al., 2008; Peschard et al., 2013). Although the current study can make no conclusions about attentional biases for faces compared to non-faces, the ANCOVA approach indicated that bias for any particular type of face did not stand out as stronger than bias for other faces. Yet, it is notable that a bias toward or away from neutral faces did not stand out either. Overall, these analyses offer one of the stricter tests of attentional biases in the literature and suggest that neither depression nor social anxiety, on their own, are related to a stronger N2pc attentional bias for any particular emotional face. However, subsequent analyses helped to clarify that attentional biases in these disorders were evident when looking more closely at each bias.

### **N2pc: Sad Face Bias**

Although the N2pc analyses showed that depression or social anxiety were not uniquely related to attentional biases, the combination of these two types of symptoms told a different story. The finding that depression was related to a greater bias toward sad faces aligns with cognitive theory and research, while the existence of bias only at low levels of social anxiety had not been shown before. This finding aligns with the general support for a bias toward sad stimuli in ERP studies examining early attention (i.e., less than 300 ms; e.g., Deng & Feng, 2012; Chen et al., 2014; Ruuhonen et al., 2020). However, other studies have not found an attentional bias (e.g., Ao et al., 2020; Yu et al., 2017), and the only other N2pc study examining bias to sad stimuli showed a bias away from sad faces compared to neutral faces for children at greater risk of depression (Gibb et al., 2016). By considering the impact of social anxiety on this sad attentional bias, the current study sheds light on a possible reason for inconsistent findings. Other

strengths of this study (i.e., comparing sad faces to a variety of other faces and using the more clearly attention-related N2pc) further bolster previous findings of a sad bias in early attention. However, it is important to note the particular pattern of bias seen in the scatter plot of N2pc-Sad against depression among those with low social anxiety. The plot indicated that attentional bias shifted from being away from sad faces at low levels of depression to a smaller bias toward sad faces as depression increased ( $r = -.28$ ). Such a pattern does not simply indicate that sad faces more consistently captured attention at higher depression, but that the tendency to attend to various non-sad faces disappeared. Rather than just having a bias toward sad stimuli, less attention for other emotional stimuli indicates potential impairment in the ability to respond appropriately to other potentially relevant stimuli.

The current study supports the cognitive theory prediction that people with depression will attend more to stimuli that fit their negative schemas (Beck, 1967; Disner et al., 2011; Lemoult & Gotlib, 2019). Stimuli expressing sadness have been viewed as particularly relevant, and much of the attentional bias literature has focused on such stimuli and neglected other negative stimuli. By including other negative faces (i.e., angry and disgust), this study, compared to previous studies, more definitively guides theories to accept that people with depression have a sad mood-congruent attentional bias rather than a general negative bias. This attentional bias is thought to reinforce one's low mood and interfere with effective coping strategies (Lemoult & Gotlib, 2019). In particular, sad-related attentional bias may contribute to difficulties in cognitive emotion regulation strategies, such as poor cognitive reappraisal and excessive rumination, which are common in depression and serve to maintain the disorder (for a review, see Liu & Thompson, 2017). In this way, sad attentional bias may strengthen the pessimistic view held by people with depression and facilitate retrieval of sad information later. In contrast, an individual



with higher social anxiety in addition to depression may experience a more dynamic attentional pattern that depends on other top-down factors known to contribute to attention (e.g., current dominant mood state, immediate history, task goals, or eye gaze avoidance). Such comorbidity is seldom considered in cognitive theories, but its importance is highlighted by this study. Theories may also be tailored by considering the timing of the attentional bias identified by the N2pc, which reflects early spatial visual attention that occurs in absence of overt eye movement. An attentional bias, however, was not detected in the RT data, indicating attention may adequately recover by 500 ms or perhaps that the neural measure of attentional bias was more sensitive. Overall, these findings suggest increased depression, coupled with lower social anxiety, quickly orients the visual brain toward depressogenic stimuli.

### **N2pc: Angry Face Bias**

As with the N2pc-Sad, the interaction between depression and social anxiety proved critical to detecting an attentional bias for N2pc-Angry. Probing this interaction revealed that the social anxiety-related bias *away from* angry faces at low and mild levels of depression shifted to a bias *toward* angry faces as depression increased. The biases away from angry faces at low/mild depression ( $r = .29$ ) and toward angry faces at higher depression ( $r = -.27$ ) were both small and similarly sized but indicate a medium effect size when considering change across the entire span of depression. The attentional bias away from angry faces contrasts with the early attentional bias *toward* angry faces found in previous studies using the N2pc (Wieser et al., 2018; Reutter et al., 2017) as well as the P1 (e.g., Mueller et al., 2009; Rossignol, Campanella, et al., 2013) and eye tracking (see Günther et al., 2021 for a meta-analysis). However, this previous research aligns with the attentional bias found in the current study when depression was high. These results clearly demonstrate the importance of considering comorbidity but show a different

pattern than other comorbidity studies, which used reaction time and found that depression suppressed the attentional bias toward threat (Grant & Beck, 2006; LeMoult & Joormann, 2012; Musa et al., 2003). By using the N2pc, the current study suggests that comorbidity may have a more dramatic effect in early attention, such that depression reverses attentional avoidance to attentional vigilance. One previous N2pc study (Wieser et al., 2018) did not find an effect of controlling for depression in their N2pc-Angry analyses, but the smaller sample size and depressive episode exclusion criteria likely reduced the ability to detect such an effect. In general, the prescreening and group approaches taken in previous N2pc studies may have resulted in different levels of social anxiety and comorbid depression; though it is worth noting that the SIAS-6 mean of 5.79 points is typical of undergraduates (Carleton et al., 2014; Cohen et al., 2019) and a moderate percentage of participants met the cutoffs for likely diagnosis of SAD (37.6%,  $n = 44$ ) and MDD (40.1%,  $n = 47$ ). Finally, in light of the null N2pc-Disgust results and the novel task design that put emotional faces in direct competition, the current results provide preliminary evidence that angry faces, compared to other threatening faces, are more salient in early attention.

Given the strict test of attentional bias in the study paradigm, this study informs cognitive theories that predict threat-related attentional bias for people with social anxiety. According to Heimberg and colleagues' (2010) theory, external attention should be driven toward social threat due to the evolutionary adaptation of quickly detecting danger and the perception of social situations as dangerous. This theory is in contrast with the finding of a social anxiety-related attentional bias *away* from angry faces when depression was low. Partially in line with results, Clark & Wells' (1995) proposed that social cues are avoided in social anxiety, as a result of enhanced self-focused attention. However, they predicted avoidance of all social cues rather than

threatening social cues specifically, so self-focused attention does not perfectly explain why more socially anxious participants avoided angry faces in favor of non-angry faces. A more likely explanation—that is highlighted by both theories—is that people with higher social anxiety (but not high depression) avoided angry faces due to experience with safety behaviors, which are behavioral adaptations learned to reduce anxiety. Avoidance behaviors, such as avoiding eye gaze, are very common among people with social anxiety (for a review, see Piccirillo et al., 2016) and a history of avoidance of threatening social cues may have contributed to the attentional bias away from angry faces. Relatively recent work has identified a suppression mechanism of attention that proactively (i.e., prior to attentional shift) inhibits attention toward salient distractor stimuli (for a review, see Gaspelin & Luck, 2020), which may have facilitated automatic avoidance of angry faces in the present study. Socially anxious individuals likely engage in this avoidance safety behavior as an attempt to regulate their anxiety, yet research on gaze avoidance (Langer & Rodebaugh, 2013) and other safety behaviors (for a review, see Piccirillo et al., 2016) suggests such strategies actually increase anxiety. As such, the bias away from angry faces in these individuals without elevated depression may contribute to maintenance of social anxiety.

For participants with elevated depression, the social anxiety-related bias *toward* angry faces may reflect reduced capacity for attentional control that would otherwise enable them to use the attentional avoidance safety behavior. Indeed, deficits in attentional control performance is noted in people with social anxiety only if they have comorbid depression (Ghadampour et al., 2017; Morrison et al., 2016) and depression may add a unique component of attentional control that is not related to trait anxiety (Judah et al. 2014; Olafsson et al. 2011). The potential importance of attentional control partially aligns with the previous finding that an N2pc bias

toward disgust faces relied on other concurrent cognitive processes (Judah et al., 2016). To the extent that co-occurring depression inhibits attentional control, it may be associated with less avoidance of and more vigilance for salient negative stimuli. Additionally, depression symptoms such as amotivation and psychomotor slowing may reduce effortful avoidance of threat and contribute to the threat-related bias. The attentional bias toward angry faces aligns with predictions by Heimberg and colleagues (2010) but indicates that theories of social anxiety may benefit from considering the role of frequent comorbidities such as depression.

### **RT: Disgust and Neutral Face Biases**

Despite no social anxiety attentional bias for disgust faces measured by the N2pc, a bias was apparent in the RT data and again showed the importance of the interaction between social anxiety and depression. Social anxiety was not related to a disgust face bias at any single level of depression, but there was a significant change in which higher social anxiety trended *away from* disgust faces at lower depression and trended *toward* disgust faces at higher depression. As such, the effect of social anxiety itself appeared smaller than in previous studies. For example, in the present study, increasing social anxiety by 7 points (e.g., from 0 to a clinical cutoff of 7 on the SIAS-6) was associated with an estimated 4.2 ms RT difference when depression was low, while some previous studies have observed about a 30 ms RT difference between social anxiety and control groups (e.g., Mogg et al., 2004; Klumpp & Amir, 2009). This fairly weak effect of social anxiety and dependence on depression fits within a history of dot-probe RT studies that have found modest and mixed effects of social anxiety on social threat attentional bias (e.g., Bantini et al., 2016; Pineles & Mineka, 2005). Given the interaction with depression in the current study, it is possible that elevated depression unknowingly contributed to previous findings of attentional bias toward threatening faces in the 500 ms range. Indeed, studies typically take a group

approach and examine high vs. low social anxiety or clinical vs. controls groups, such that strict social anxiety inclusion guidelines may have amplified the occurrence of comorbidities like depression. In the present study, the effect of depression mirrors the N2pc-Angry finding such that social anxiety may facilitate the safety behavior of disgust face avoidance, which is reversed when depression is high. This pattern may reflect the poor cognitive control and negativity bias associated with depression. However, dot-probe RT is not as straightforward to interpret as the N2pc and other interpretations must be considered.

Unlike the initial orientation of attention assessed by the N2pc, RT after a 500 ms stimulus presentation may follow a shift from the first location of attention (Rooijen et al., 2017). Indeed, an attentional shift could be initiated by an overt saccade eye movement in as little as 200 ms (Sumner, 2011). An RT bias at this time point could still be interpreted as avoidance (at lower depression) or vigilance (at higher depression) but it is unknown what preceding attentional process may have contributed to attention at this later time period (i.e., initial perception of a disgusted face drives subsequent focus on the opposing face). The potential early saccades may also have simply diminished the RT bias at this time frame, as found in one previous study (Petrova et al., 2013). Some research suggests that dot-probe RTs actually represent difficulty with attentional disengagement (i.e., holding attention on a stimulus when task goals demand attention elsewhere; Koster et al., 2004; Taylor et al., 2016). If that is the case, the RT biases for disgust faces may suggest that social anxiety is related to slightly prolonged attention toward neutral faces (at lower depression) and disgust faces (at higher depression) when the task relevant goal was to attend elsewhere. Theories of attentional bias contend that the difficulty disengaging from threat when both social anxiety and depression were high may represent strategic effort to closely evaluate the threat (Cisler & Koster, 2010). This

bias is thought to be mediated by poor attentional control and result in increased anxiety (Bar-Haim et al., 2007; Cisler & Koster, 2010). Extending these theories to the social anxiety bias away from disgust faces at elevated depression, difficulty disengaging from non-disgust faces may reflect a strategic attempt to seek safety and reduce anxiety. Although precise interpretation of the processes contributing to the RT bias is difficult, these results lend support to a threat-based attentional bias in social anxiety. As with the N2pc analyses, results show how various combinations of social anxiety and depression influence attentional engagement with signs of threat or safety.

Researchers have typically shown little interest in the neutral stimulus and instead interpret biases in relation to the emotional stimulus that is paired with the neutral one. The current study, however, was particularly suited to examine effects of neutral stimuli, which indicated RT attentional biases compared to the combination of all emotional faces. The reason that participants with elevated depression attended away from neutral faces is perhaps due to the increased threat they associate with ambiguity. Individuals with depression tend to interpret ambiguous (e.g., neutral) social stimuli as more negative than other individuals (e.g., Douglas & Porter, 2010; Everaert et al., 2017; Maniglio et al., 2014), which may be caused by the decreased perceived pleasantness of such stimuli (Lin et al., 2019). This bias away from ambiguity may also be interpreted as increased attention toward generally emotionally salient stimuli, which was previously reported in a meta-analysis of Stroop RT tasks (Epp et al., 2012) and the 100 ms condition, but not the 500 ms condition, of a dot-probe RT task (Trapp et al., 2018). Attending toward all emotional stimuli may fit the model posited by emotional context insensitivity theory, which states an evolutionary function of depression is to reduce risky or unsuccessful activity through attenuated mood reactivity to any emotional stimuli (Rottenberg & Hindash, 2015).

From this perspective, excessive attention toward emotional stimuli could ensure that all emotional content is considered and thus facilitate control over emotional reactivity.

In contrast, and as discussed previously, people with social anxiety frequently regulate emotions through the safety behavior of avoiding cues of social threat. The social anxiety-related attentional bias toward neutral faces suggests individuals may have learned to (ineffectively) manage anxiety by avoiding any type of emotional cues from others. Indeed, social anxiety may be characterized by fear of both negative and positive evaluation (e.g., Weeks et al., 2008; Rodebaugh et al., 2012), such that reduced attention to even happy faces may be expected. As seen in the attentional biases discussed previously, higher levels of depression was associated with reduced social anxiety-related attentional avoidance. This suggests that depression is associated with attenuation of the attentional avoidance safety behavior, perhaps through dysfunction in cognitive control. Meanwhile, higher social anxiety was related to a greater effect of depression on avoiding neutral faces, which may reflect the enhanced relevance of disgust and angry faces to these individuals. Although it is not possible to discern the precise attentional process reflected in RT data, these findings clearly provide evidence that the neutral vs. emotional contrast is an important facet of attention in depression and social anxiety.

### **Clinical Implications**

Most treatment research that targets attentional biases has examined an intervention called attentional bias modification (ABM). ABM trains attention to focus less on disorder-related stimuli and more on neutral stimuli through computer-based tasks in which performance is rewarded for attending to the neutral stimuli. Meta-analyses have shown significant reductions in social anxiety symptoms after ABM, but the effects are small (Heeren et al., 2015; Mogoşe et al., 2014) and the effects on depression appear less consistent (Mogoşe et al., 2014; Beevers et

al., 2015). As a result, ABM needs additional research and modification before it can be recommended for wide-scale implementation (Pelissolo et al., 2019). The current study suggests that procedures for social anxiety ABM may be improved by considering that attention may already be biased to avoid threatening cues. Training all clients to attend more to neutral cues and less to threatening may actually reinforce the potential avoidant safety behavior and increase symptoms over time. The treatment approach for modifying attention may also differ for subgroups social anxiety (Pelissolo et al., 2019). Indeed, the current findings suggest the importance of co-occurring depression levels, such that techniques to counter avoidance may only be relevant when depression is low.

Regarding depression-related biases, the current study encourages further research on using ABM to train attention away from sad stimuli. Although findings in the depression ABM literature are mixed (Mogoase et al., 2014), effects may be clarified by using the N2pc as a measure of change in attentional bias toward sad faces. Indeed, using the N2pc in ABM has been successfully applied for social anxiety (Reutter et al., 2017). Additionally, using ABM to target biases for general emotional cues or neutral cues may address general dysfunction in mood reactivity or the tendency to misinterpret ambiguous cues. Future depression ABM research should also consider individuals' level of social anxiety, as modifying the bias toward sad faces may only be relevant for those with low social anxiety. Even though ABM often uses behavioral methods to assess and alter biases, the current study shows that using EEG-based neurofeedback may address biases that would otherwise be missed. Indeed, using neurofeedback to alter attention-related brain response to negative stimuli is a promising treatment technique in need of further research (Mennen et al., 2019).



Another potential strategy for altering attentional biases is exposure therapy, which involves exposure to a feared or avoided object/situation and is commonly used to treat social anxiety (Pelissolo et al., 2019). Researchers have suggested that attentional exposure to external threat (e.g., eye contact with others) may increase the effectiveness of exposure therapy by removing attentional avoidance as a safety behavior and demonstrating to the habituation of related anxiety (Langer & Rodebaugh, 2013; Weeks et al., 2019, see Barry et al., 2015). Although one RT study showed no effect of social anxiety exposure therapy on attentional bias (Kampmann et al., 2018), a smaller study found that exposure therapy reduced bias when examining subgroups of those who avoided threat and those who were vigilant to it (Calamaras et al., 2012). In a similar way, the current study indicates that subsets of clients may benefit from guided practice in attending to or away from cues of negative evaluation, depending on co-occurring depression severity. Altering attention-related safety behaviors may help clients learn to tolerate threatening facial cues or more fairly perceive their environment, which can provide opportunities for cognitive reappraisal of negative evaluation (Blakey & Abramowitz, 2016). Although learning and practice may alleviate attentional biases, some clients may find this task difficult, particularly given the rapid nature of biases detected in the current study. As such, pharmacological aids may be effective supplements to improve treatment. In particular, testosterone has been shown to increase fixation on angry faces in people with social anxiety (Enter et al., 2016; Terburg et al., 2016). Testosterone appears to affect attentional biases by reducing amygdala response during threat avoidance (Radke et al., 2015) and its use with social anxiety is consistent with the threat avoidance biases described in the current study.

Threat-related exposure is not typical of depression treatment, but exposure-like behavioral strategies may be leveraged to address symptoms (Hayes et al., 2007). For example,

behavioral activation (BA) challenges clients to engage in avoided activities (e.g., visiting a café) in order to improve mood and reduce depressive rumination. The current study suggests BA could be augmented by asking clients to monitor their attention during BA exercises and practice immediately focusing on non-depressive stimuli (e.g., the satisfied coffee drinker in a café vs. the worn-down barista). To assist with distress tolerance and attentional control, Hayes and colleagues (2007) included mindfulness in their exposure-based cognitive therapy for depression. This mindfulness intervention is designed to help clients regulate attention and reduce rumination, which, when done in the early phase of treatment, may allow them to engage in new activities more fully (Kumar et al., 2008). Targeting attentional control through this combination of mindfulness and exposure may be a valuable intervention for individuals with elevated depression but little co-occurring social anxiety, as they showed the attentional vigilance in the current study. Additionally, learning to reduce these attentional biases may be bolstered by medication. Serotonergic antidepressant medication has been repeatedly used to reduce biases toward depressive stimuli, and so it may help individuals overcome such rapid attentional biases.

Psychoeducation is often integrated into depression and social anxiety treatment (Leahy et al., 2012) and can reduce symptoms and increase treatment adherence (Jones et al., 2018; Trusi et al., 2013). The theoretical implications described throughout the previous sections indicate that clients may benefit from specific attention-related psychoeducation. In expanding a discussion on the patterns of avoidance in social anxiety, therapists may describe the tendency to automatically attend away from facial expressions, such as anger, that trigger their anxiety. Introducing this pattern as a safety behavior would demonstrate how attentional processes can guide emotion and behavior, thus motivating efforts to change biased attention. Psychoeducation should also highlight that depression is related to hyper-attention to sad social stimuli and open

discussion of how this can maintain low mood. Therapists can probe clients for potential difficulty with controlling attention and explain that this may contribute to rapid, unconscious attentional bias toward social cues of sadness or other strong emotions. Describing attentional biases based on interacting levels of depression and social anxiety would help clients recognize their own specific experiences and motivate engagement in therapy. Psychoeducation on these aspects of attention may improve treatment and reduce client self-stigma as they understand the automatic cognitive processes involved symptoms (Cho et al., 2020).

### **Limitations**

The results of this study should be set in the context of its limitations. More participants than expected were excluded for having too few valid N2pc trials. This may have been a result of the length of the study task, during which electrodes could become disconnected and participant movement could increase. Using a convenience sample of undergraduate students of young adults limits the generalizability of this study in several ways. Despite no clear pattern that depression and social anxiety attentional biases vary by age (see Günther et al., 2021; Peckham et al., 2010), such an effect could have contributed to finding an N2pc-Sad bias opposite of that in children at-risk for depression (Gibb et al., 2016). N2pc studies on social anxiety have exclusively recruited undergraduate students, so research across the life span is needed. Results may not generalize beyond the level of symptom severity experienced by the current sample, and self-reported symptoms may not accurately reflect clinical diagnosis. Self-reporting one's symptoms is also limited by demand characteristics and social desirability. Further, history of social anxiety was not assessed and history of depression was only assessed in a subsample, though these factors may impact attentional biases (Elgersma et al., 2018; Zvielli et al., 2016). As the first study to examine the N2pc in current depression—rather than in children at-risk for

depression—research is needed in current depression as well as clinically diagnosed and remitted groups. The study task design limits interpretation of attentional biases to specific timepoints in the attention process. This may account for differences from previous research using other ERPs (e.g., P1), in addition to novel elements of the study such as direct comparison of various emotional faces and focus on comorbidity. In order to restrain the length of the task, the number of pairings was insufficient to compare specific pairings (e.g., angry vs. disgust) instead of comparing one face type to all others. Future research could expand the number trials for each pairing by including fewer types of faces. The effects of the racial or gender identity of the participants and stimulus faces could not be examined in the current study but could alter attentional biases by activating fears based on experience and stereotypes (e.g., Carr et al., 2016; Trawalter et al., 2008; Zhao et al., 2014). Finally, the N2pc and RT attentional biases noted in this study were generally numerically smaller than found in similar studies, suggesting that biases with competing emotional faces may be more difficult to detect.

## **CHAPTER V**

### **CONCLUSIONS**

Selective attention plays a crucial role in how humans interact with and respond to the external world. The diverse top-down goals and experiences of individuals blend with the physical bottom-up properties of the environment to select what information is worthy of precious cognitive resources. Even as cognitive theories have incorporated attention into our understanding of depression and social anxiety, research has produced little consensus on exactly how attention is altered within these disorders and their high comorbidity is rarely considered. The current study included a novel and strict test of attentional biases across depression and social anxiety by comparing biases for a variety of emotional faces that competed for attention and utilizing the N2pc to measure attention on a neural level.

Facial expressions theoretically relevant to depression (i.e., sad, happy) and social anxiety (i.e., anger, disgust) were expected to produce attentional biases as symptom severity increased. When comparing potential attentional biases to each other, no particular bias appeared stronger than the others for either depression or social anxiety. However, when considering biases on their own and accounting for co-occurring depression and social anxiety, several attentional biases emerged. For depression, the N2pc showed a bias toward sad faces, but only at low levels of social anxiety, and RT showed a bias away from neutral faces, but only at mild to high levels of social anxiety. These analyses indicate that, for these individuals, early attention is guided toward sad social stimuli and that various strong emotional cues may attract attention a little later. This perhaps reflects difficulty with attentional control as well as the particular salience of depressive mood-congruent stimuli. Moreover, results indicated that social anxiety is more likely marked by attention moving away from threatening social stimuli. Angry faces and

disgust faces, as measured by the N2pc and RT respectively, tended to be avoided at higher levels of social anxiety, only when depression was low. These findings suggest that social anxiety may be associated with using attentional avoidance as a (counterproductive) way to reduce anxiety. Since this avoidance likely requires sufficient levels of attentional control, depression-related attentional control deficits may help explain why, at higher levels of depression, the social anxiety attentional biases tended to be *toward* the socially threatening social stimuli. These results emphasize that co-occurring depression and social anxiety should be accounted for when addressing attentional biases for social cues. Theorists and clinicians should continue to consider the automatic pull of symptom-congruent social stimuli in depression and social anxiety, while also recognizing the relatively overlooked attentional *avoidance* in social anxiety. Careful application of these findings will help people with depression and social anxiety more fairly view the world around them.

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## **APPENDIX A**

### **Self-report Measures**

### Demographics

1. What is your age? \_\_\_\_\_
2. What is your student status?  
☐ Full-time    ☐ Part-time
3. What is your class standing?  
☐ Freshman  
☐ Sophomore  
☐ Junior  
☐ Senior  
☐ Graduate  
☐ Other (please specify) \_\_\_\_\_
4. Current residence:  
☐ On-campus dormitory  
☐ On-campus living-learning community  
☐ Off-campus house or apartment  
☐ Greek-affiliated residence (fraternity/sorority)  
☐ With family  
☐ Other (please specify) \_\_\_\_\_
5. What is your GPA? \_\_\_\_\_
6. What is your involvement in social fraternities or sororities?  
☐ A current member  
☐ Currently pledging  
☐ Not a member, but regularly or occasionally attend Greek social events  
☐ Not a member, and do not attend Greek events
7. Are you currently employed?  
☐ I am not employed  
☐ I typically work about 20 hours or less per week  
☐ I typically work about 20 to 35 hours per week  
☐ I typically work more than 35 hours per week  
☐ Other (please specify) \_\_\_\_\_
8. What is your gender?  
☐ Male        ☐ Female        ☐ Trans\*        ☐ Other
9. What is your relationship status?  
☐ Single

- ☐ Married
- ☐ Divorced / Separated
- ☐ In a committed relationship
- ☐ Other (please specify) \_\_\_\_\_

10. Are you Hispanic or Latino?

- ☐ Yes            ☐ No

11. My ethnicity is (select all that apply):

- ☐ Black, African American, Afro-Caribbean, Black African, Other in this category.
- ☐ White, Caucasian, European American, White European, Other in this category.
- ☐ East Asian, Asian American, Amerasian, Asian-Caribbean, Other in this category.
- ☐ Latino/a, Hispanic, Spanish, Latin American, of Spanish speaking-South American/Caribbean heritage, Other in this category.
- ☐ South Asian, South Asian American, of South Asian heritage, Other in this category.
- ☐ Middle Eastern, Arab, Non-Black North African, Other in this category.
- ☐ Native American, American Indian, Alaskan Native, Other in this category.
- ☐ Pacific Islander, Other in this category.

12. How do you define your sexual identity? Would you say that you are:

- ☐ Only homosexual
- ☐ Mostly homosexual
- ☐ Bisexual
- ☐ Mostly heterosexual
- ☐ Only heterosexual
- ☐ Other (please specify) \_\_\_\_\_.

**PHQ-9**

Over the last 2 weeks, how often have you been bothered by any of the following problems?

	Not at all	Several days	More than half the days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much.	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself – or that you are a failure or have let yourself or your family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you have been moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or of hurting yourself in some way	0	1	2	3

**SIAS-6**

For each question, please indicate the degree to which you feel the statement is characteristic or true of you.

	Not at all	Slightly	Moderately	Very	Extremely
1. I have difficulty making eye contact with others.	0	1	2	3	4
2. I find it difficult mixing comfortably with the people I work with.	0	1	2	3	4
3. I tense up if I meet an acquaintance on the street.	0	1	2	3	4
4. I feel tense if I am alone with just one person.	0	1	2	3	4
5. I have difficulty talking with other people.	0	1	2	3	4
6. I find it difficult to disagree with another's point of view.	0	1	2	3	4



**LMDE**

1. Have you ever had periods of time that lasted several days or longer when you felt sad, empty, or depressed most of the day?

No (*Skip to item 3*)

Yes

2. During the episodes of being sad, empty, or depressed, did you ever lose interest or pleasure in most things like work, hobbies, or other things that you usually enjoy?

No (*Skip to item 4*)

Yes (*Skip to item 4*)

3. Have you ever had periods of time that lasted several days or longer when you lost interest or pleasure in most things like work, hobbies, or other things you usually enjoy?

No (*End of assessment*)

Yes

4. You mentioned having periods of time that lasted several days or longer when you [*were sad and (or) lost interest or pleasure in most things*]. Did you ever have a period of this sort that lasted most of the day nearly every day for two weeks or longer?

No

Yes

## VITA

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### **Education and Training**

- Ph.D.**      **Virginia Consortium Program in Clinical Psychology, Norfolk, VA**  
(APA Accredited)  
Clinical Psychology, 2023 (Expected)  
Advisors: Matt R. Judah, Ph.D. and Catherine R. Glenn, Ph.D.
- M.S.**      **Old Dominion University, Norfolk, VA**  
Experimental Psychology, 2019  
Advisor: Matt R. Judah, Ph.D.
- B.A.**      **Wake Forest University, Winston-Salem, NC**  
Psychology, 2013

### **Background**

Nathan M. Hager is in his fifth year of graduate studies in the Virginia Consortium Program in Clinical Psychology. He is currently on his pre-doctoral clinical internship at the Stony Brook University Consortium Internship Program. He has worked in the Emotion Research and Psychophysiology Laboratory at Old Dominion University with mentors Dr. Matt R. Judah and Dr. Catherine R. Glenn. His research uses psychophysiological methods to examine cognitive and reward-related deficits in depression and anxiety disorders.

### **Selected Peer-reviewed Publications and Poster Presentations**

**Hager, N. M.,** Judah, M. R., & Milam, A. L. (2022). Loneliness and depression in college students during the COVID-19 pandemic: The role of boredom and repetitive negative thinking. *International Journal of Cognitive Therapy, 15*, 134-152. <https://doi.org/10.1007/s41811-022-00135-z>

**Hager, N. M.,** Judah, M. R., Rawls, E. (2022). Win, lose, or draw: Examining salience, reward memory, and depression with the reward positivity. *Psychophysiology, 59*(1), 1-19. <https://doi.org/10.1111/psyp.13953>

Judah, M. R., **Hager, N. M.,** Nako, K., Blanchette, D. R. (2019). Gaze Avoidance Explains the Association Between Anxiety Sensitivity Social Concerns and Social Anxiety. *International Journal of Cognitive Therapy, 1-12*. <https://doi.org/10.1007/s41811-019-00050-w>