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Effect of Social Anxiety on Trial-by-Trial Changes in Attentional Biases To Emotional Faces

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EFFECT OF SOCIAL ANXIETY ON TRIAL-BY-TRIAL CHANGES IN ATTENTIONAL BIASES TO EMOTIONAL FACES

A dissertation defense submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

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Abstract

Cognitive research suggests that many anxiety disorders, including social anxiety disorder, are associated with an increased attentional bias toward potentially threat-related stimuli. However, inconsistent findings suggest the effect of anxiety on attentional bias to threat is not direct and that other factors, including emotion, perceptual load, and time on-task, impact the relationship between social anxiety and attentional biases to facial stimuli. In the present study, 157 undergraduate students completed a computerized letter search task identifying one of two target letters (N or X) from a circular arrangement of different letters (high load) or dots (low load). In 20% of trials, an emotional (angry, happy, or fearful) or neutral distractor face would appear in the center of the screen. Participants’ reaction times were used to compare attentional biases towards the different facial stimuli, with slower reaction times indicating greater attentional capture by distractor faces. Multilevel modeling (MLM) was used to assess trial-by-trial changes in how attentional capture by distractor faces during a letter search task is affected by social anxiety (as measured by SPAI-23 scores), emotion type (angry, fearful, happy, or neutral), perceptual load (high or low), and time on-task. It was hypothesized that attentional biases, as measured by reaction times, would be dependent on the interactions between all of these factors. Specifically, it was predicted that participants with high social anxiety would show an increased attentional bias towards angry and fearful faces. Instead, the present study found that participants with high social anxiety showed less attentional bias towards angry and fearful faces as compared to participants with low social anxiety, suggesting that social anxiety promotes increased avoidance of threat-related social stimuli. Implications for the treatment of social anxiety disorder are discussed.
EFFECT OF SOCIAL ANXIETY ON TRIAL-BY-TRIAL CHANGES IN ATTENTIONAL BIASES TO EMOTIONAL FACES

Around the world, anxiety disorders are among the most prevalent of any psychiatric condition (Stein et al., 2022) and rank within the top ten causes of injury among adolescents and adult women (Vos et al, 2020). In conjunction with the increased stress associated with the COVID-19 pandemic, the prevalence of anxiety disorders is predicted to increase, with one review estimating a 25.6% increase in the global prevalence of anxiety disorders between January of 2020 to January of 2021 (Santomauro et al, 2021). Social anxiety disorder, characterized by excessive fear or anxiety of social situations and of being negatively judged by others, is one of the most common anxiety disorders (American Psychiatric Association, 2013). Social anxiety disorder can significantly impact an individual’s ability to engage in social activities and to form and maintain meaningful relationships with others.

A notable and impairing symptom of social anxiety disorder is hypervigilance. Many researchers theorize that the cognitive mechanism behind hypervigilance, attentional bias towards potentially threatening stimuli, serves as a causal and maintaining factor in clinically elevated anxiety (Beck & Clark, 1997; Mathews & MacLeod, 1994) and social anxiety disorder in particular (Clark & Wells, 1995; Rapee & Heimberg, 1997). Greater attentional biases to threat make individuals with high levels of anxiety more likely than those with lower levels of anxiety to perceive stimuli as threatening, and as a result high-anxiety individuals notice potentially threatening stimuli at a much higher rate than threat realistically appears (Mathews, 1990). Noticing more potential threats generates greater fear and anxiety, which in turn validates the individual’s hypervigilance and further promotes attentional bias to threat in the future.
This theory that attentional bias to threat causes and maintains anxiety symptoms prompted the development of Attention Bias Modification, a computerized intervention which aims to reduce attentional bias to threat. Initial studies suggested that Attention Bias Modification could be used to treat social anxiety disorder (Amir et al., 2009b; Beard et al., 2011; Hakamata et al., 2010), however more recent data finds that while Attention Bias Modification does reduce attentional biases to threat, it is ineffective at reducing social anxiety disorder symptoms (Cristea et al., 2015; Hang et al., 2021; Heeren et al., 2015). The unexpected ineffectiveness of Attention Bias Modification indicates that although social anxiety disorder is associated with greater attentional bias to threat, other factors may be involved in the relation between these two variables. The existence of moderating factors is also implied by inconsistent findings in the emotional face literature. Early investigations into attentional biases to emotional faces found that angry faces attract attention more effectively than other types of emotional expressions (Anger Superiority Effect, Hansen & Hansen, 1988; see also Hahn & Gronlund, 2007; Horstmann & Bauland, 2006; Krysko & Rutherford, 2009; Lipp et al., 2009). More recent studies, however, find that happy, not angry, faces attract greater attentional bias in visual search (Happiness Superiority Effect, Juth et al., 2005; see also Bucher & Voss, 2019; Horstmann et al., 2012; Horstmann & Becker, 2020; Öhman et al., 2010). These findings do not align with traditional understandings of preferential attention for threat-related information. Yet, a multitude of studies support a correlation between increased attentional bias to threat and heightened symptoms of social anxiety (for systematic reviews and meta-analyses on this topic, see Bantin et al., 2016; Bar-Haim et al., 2007; Cisler & Koster, 2010; Clauss et al., 2022; Dudeney et al., 2015; Goodwin et al., 2017; Günther et al., 2021; Mathews & MacLeod, 1994; Ruiz-Caballero & Bermúdez, 1997; Shi et al., 2022). The presence of a correlation between
increased attentional bias to threat and social anxiety in the face of inconsistent Attention Bias Modification and Anger Superiority Effect findings indicates an indirect correlation moderated by additional factors.

**Emotion as a Moderating Factor**

Emotion may serve as a moderating factor in the relation between increased attentional biases and anxiety. Although high anxiety populations tend to exhibit greater attentional biases to angry expressions, (Ashwin et al., 2012; Bar-Haim et al., 2007; Berggren & Eimer, 2020; Bradley et al., 1999; Gilboa-Schechtman et al., 1999), this may reflect a lower threshold for threat tolerance as opposed to an explicit bias for threat. Indeed, individuals with high anxiety are more likely to interpret neutral or ambiguous stimuli as threatening than those with lower levels of anxiety (Cooney et al., 2006; Richards et al., 2002; Winton et al., 1995). Similarly, high anxiety individuals demonstrate increased perception of fearful faces, which can be conceptualized as ambiguous or indirect sources of threat (Eimer & Kiss, 2007; Richards et al., 2002).

Nevertheless, attentional biases to emotional stimuli in highly anxious samples is dependent on more than just level of threat. In one study, a letter search task was used to find that task-irrelevant emotional faces interfered with task performance for participants with high, but not low, social anxiety at high perceptual load (high visual complexity) conditions (Soares et al., 2015). This did not hold true for conditions of low perceptual load (low visual complexity), where there was no difference between high and low social anxiety groups. While it is typically expected that task-irrelevant distractors cannot be processed when a primary task is sufficiently visually complex, some researchers suggest that anxiety is related to global impairments in goal-oriented attentional control, and as such people with high levels of anxiety may experience
increased attentional capture by task-irrelevant threat distractors at high perceptual loads. Thus, perceptual load may also operate as a moderating factor in the relation between anxiety and attentional bias.

Additionally, attentional biases are known to fluctuate over time (Zvielli et al., 2015). Specifically, individuals with anxiety tend to demonstrate patterns of increased initial attentional bias to threat-related stimuli followed by periods of avoidance (Mogg et al., 1997; Mogg et al., 2004). To account for the temporal fluctuations in attentional biases from one trial to the next, as well as to analyze the changes within the complex interactions between anxiety levels, emotion, and perceptual load, it is necessary to use multilevel modeling. Multilevel modeling (MLM) offers a method of analyzing changes over time without the data loss associated with mean aggregation (Gade et al., 2022; McGlade et al., 2020).

The proposed study will use MLM to analyze trial-by-trial reaction time changes on a letter search task in order to investigate how attentional biases to distractor faces are affected by 1) social anxiety (as measured by SPAI-23 scores), 2) emotion type (angry, fearful, happy, or neutral), 3) perceptual load (high or low), and 4) time on-task. It is hypothesized that attentional biases, as measured by reaction times, will be dependent on the interactions between all of these factors.

**Social Anxiety Disorder**

Social anxiety disorder describes a persistent fear or anxiety about social situations and being negatively judged by others (American Psychiatric Association, 2013). Common situations that promote social anxiety include meeting new people, making small talk, being observed while eating or performing other common activities, and giving a public presentation. Individuals with social anxiety disorder often avoid these anxiety-provoking situations, or else endure them
with great discomfort. These patterns of avoidance can significantly impair the individual’s ability to engage in crucial social experiences and to form and maintain meaningful relationships.

The DSM-5 reports the worldwide prevalence of social anxiety disorder being between 2-7%, with greater rates seen in the United States as compared to European countries (American Psychiatric Association, 2013), although more recent findings are suggestive of higher global rates of social anxiety disorder, particularly among adolescents and young adults. One study sampling young adults from seven culturally and economically diverse countries found that between 22.9 and 57.6% of participants met criteria for social anxiety disorder (Jefferies & Ungar, 2020). Consistent with the DSM-5 data, young adults from the United States demonstrated the highest rates of social anxiety disorder. Life stressors, such as the ongoing COVID-19 pandemic have also been shown to affect the severity of social anxiety. Hawes et al. (2021) compared youths’ pre-COVID-19 symptom measures with assessments completed between March 27 and May 15 of 2020 and found an overall 29.5% increase in social anxiety disorder. At the same time, results showed social anxiety symptoms decreased in correlation with home confinement, suggesting that the social anxiety disorder psychopathology was less relevant when engaging in social situations was discouraged. This warrants some concern since the end of the pandemic will mean a resuming of in-person activities. Individuals with social anxiety disorder will again be confronted with anxiety-provoking social situations for the first time in months, which could trigger significant distress and cause greater social impairment in the future.
Cognitive Theory of Social Anxiety

A key feature of clinical anxiety is the enhanced perception of potentially threatening information (Beck & Clark, 1997; Clark & Wells, 1995; Mathews & MacLeod, 1994; Rapee & Heimberg, 1997). The primary threat that individuals with social anxiety disorder respond to more readily is social threat (e.g., social exclusion, negative appraisal by others, loss of social connections; Trower & Gilbert, 1989). Numerous cognitive-behavioral models propose that individuals with social anxiety disorder operate under the assumption that they are poor social actors, generating a positive feedback loop that perpetuates their anxiety; individuals with social anxiety disorder attribute excessively high standards to social interactions (Rapee & Heimberg, 1997) and exhibit a strong desire to meet those standards (Clark & Wells, 1995; Rapee & Heimberg, 1997), while also believing that they are fundamentally incapable of meeting those standards (Beck & Clark, 1997; Clark & Wells, 1995; Rapee & Heimberg, 1997). Before entering a social encounter, individuals with social anxiety disorder will typically feel anxious due to their existing negative associations with social situations (Clark & Wells, 1995). This anxious state may prompt mood-congruent memories of similar past events that triggered anxiety and may make them predict that the upcoming social event will have a similarly negative outcome (Clark & Wells, 1995; Mathews & MacLeod, 1994).

Upon entering a social situation, the individual with social anxiety disorder will demonstrate enhanced attention for information related to potential social threat. Specifically, the individual will preferentially attend to internal cues (e.g., increased heart rate, hyperventilation, sweating, dizziness, nausea) and external cues (e.g., other people’s facial expressions and body language, ambiguous interactions) that could indicate possible social disapproval (Beck & Clark, 1997; Clark & Wells, 1995; Mathews & MacLeod, 1994; Rapee & Heimberg, 1997). By
preferentially attending to threat, these individuals actually cause themselves to encounter more threat-related information, creating the illusion that their environment is laden with danger. All this further heightens their anxiety. In their anxious state, individuals with social anxiety disorder will often behave in a manner that is interpreted by others as unfriendly (e.g., avoiding eye contact, keeping to oneself), which prompts others to perpetrate similar behaviors in return (Clark & Wells, 1995). This exchange confirms the individual’s pre-existing beliefs regarding their inherent inability to succeed in social interactions (Beck & Clark, 1997; Clark & Wells, 1995; Rapee & Heimberg, 1997). In this manner, individuals with social anxiety disorder complete the maladaptive, self-perpetuating cycle of anxiety.

**Attentional Bias to Threat**

The high personal and societal cost of social anxiety disorder highlights the importance of finding effective treatment options. To this end, researchers have been studying the underlying mechanisms that cause and perpetuate social anxiety disorder. Assuming that increased attentional allocation towards potentially threat-related stimuli does in fact contribute to the development of social anxiety disorder, as proposed in the aforementioned cognitive theories (Clark & Wells, 1995; Rapee & Heimberg, 1997), it is first necessary to understand how visual attention functions and how this function may be different for those with high social anxiety.

**Selective Visual Attention**

Individuals are constantly presented with an excess of new information, which must be processed before it can be incorporated into our understanding of the world (Desimone & Duncan, 1995). However, the human brain is limited in the amount of information it can process at any one time. It is therefore by necessity that our attention is selective. Environmental stimuli are in continuous competition for our attention, and whether to process or ignore visual
information is determined by a combination of cognitive mechanisms, which are traditionally divided into bottom-up and top-down processes (Theeuwes, 2010). Bottom-up visual processes (also known as automatic or exogenous processes) are primarily driven by sensory input, meaning that a stimulus’ physics features (e.g., color, shape, texture) determine whether the stimulus will successfully capture one’s attention. Bottom-up processes operate quickly and without one’s conscious control. In contrast, top-down visual processing (also known as strategic or endogenous processing) is volitional and goal-directed, typically taking more time than bottom-up processes. Bottom-up and top-down processes work in tandem with other factors, including priming, value, and semantic context, to create a priority map that guides attention towards the stimuli deemed to be most relevant in the environment (Theeuwes & Failing, 2020; Wolfe, 2021).

Both bottom-up and top-down processes are instrumental in target identification and attention allocation, however the relative importance of bottom-up and top-down processes in directing attention has been debated. The early selection model, also known as Broadbent’s (1958) filter model, emphasizes the role of bottom-up processing by proposing that selective attention works by establishing feature-dependent cognitive “filters” that help discriminate between task-relevant and task-irrelevant stimuli. While the early selection model explains slower reaction times when task-switching, it fails to explain why personally relevant, but task-irrelevant, stimuli can still capture attention (cocktail party effect, Shapiro et al., 1997). The late selection model, in contrast to the early selection model, suggests that all information, regardless

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1 To elaborate briefly, priming refers to the saliency associated with one’s past experiences (or “history”) with a given stimulus, value refers to any reward or punishment that may be associated with the stimulus, and semantic context (or “scene”) refers to the meaning one assigns to the surrounding environment in which the stimulus is found. These concepts represent relatively recent additions to well-established theories of visual search and are beyond the scope of this paper. Please refer to Theeuwes and Failing (2020) and Wolfe (2021) for more details regarding modern visual search theories.
of task-relevance, is cognitively processed. The late selection model emphasizes the role of top-down processing by theorizing that a cognitive “filter” is applied after the first stage of general processing is completed (Deutsch & Deutsch, 1963; Duncan, 1980). Although the late selection model resolves the “cocktail party effect” issue associated with the early selection model, it exaggerates human processing capabilities, thus failing to account for human neurological limits (Desimone & Duncan, 1995; Lavie, 1995).

Perceptual load theory (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994) strikes a balance between early and late selection models by positing that target identification may occur in either the early or late stages of attentional processing, depending on perceptual load. Perceptual load describes the degree of visual complexity portrayed by a scene, with a high load indicating increased complexity and a low load indicating decreased complexity. A task imposing a high perceptual load makes it difficult to identify a target stimulus from among non-targets, meaning that nearly all available cognitive resources must be utilized to successfully complete the task. As a result, few (if any) cognitive resources remain for processing task-irrelevant stimuli (Lavie, 2005). In contrast, a low perceptual load engages fewer cognitive resources, leaving the unengaged resources to be automatically, and unconsciously, reallocated for processing available task-irrelevant stimuli (Lavie et al., 2004).

**The Fear Module**

From an evolutionary perspective, threatening stimuli hold crucial and time-sensitive safety information. Thus, an increase in attention to threat-related information, also referred to as attentional bias to threat, would likely improve an organism’s chance of survival. Attentional bias to threat can be understood using Öhman and Mineka’s (2001) proposed Fear Module, which describes an underlying neural circuitry that ensures stimuli associated with deadly threat
are automatically and unconsciously attended to when present in the environment. The Fear Module directs attention towards threat by acting on both bottom-up and top-down processes, but in opposite ways. Broadly speaking, bottom-up processing is bolstered whereas top-down processes are suppressed. The resulting priority map is weighted in favor of processing threat-related stimuli over processing goal-related stimuli. This is best illustrated by example. Imagine that an individual has dropped their keys in the grass next to an exceptionally frightening spider. Upon looking down for their keys, top-down processes prioritize searching for the shiny, key-shaped object they seek whereas bottom-up processes will prioritize attending to the squirming, eight-legged creature nearby. According to the Fear Module, humans have adapted to prioritize bottom-up processes when a potential threat is present in the environment, and despite the individual’s desire to find their keys it is likely that they will direct their attention to the spider instead (at least initially).

Numerous studies have been conducted to assess attentional bias to threat, with one of the more commonly used ones being the computerized visual search task (Treisman & Gelade, 1980). The visual search task presents participants with a stimulus array from which the participants must attempt to identify a given target. Participants typically complete multiple trials and their performance, as measured by reaction time (RT), is recorded for each trial. Smaller (faster) RTs typically indicate superior performance whereas larger (slower) RTs indicate worse performance on the target identification task. Results from visual search studies have been used to support the Fear Module theory. For example, Öhman et al. (2001) used a visual search task to examine attentional biases to evolutionary significant sources of threat. Participants were shown a 3x3 matrix of images (selected from pictures of snakes, spiders, flowers, or mushrooms) and were asked to determine whether all the images fit into one category or whether one image was
discrepant. It was found that participants were significantly faster at identifying single images of snakes or spiders within matrices composed mostly of flowers or mushrooms than they were at identifying discrepant flowers or mushrooms within snake or spider matrices, suggesting superior attentional capture by threat-related stimuli. Similarly, Anderson and Britton (2020) conducted a visual search study featuring an array of shapes. All shapes in the array were identical except a single target (which had a unique geometry) and a single distractor (which had a unique color). Participants were instructed to fixate on the target and were warned that they would receive an electric shock for fixating on the distractor. Yet despite the shock, the researchers found that participants selectively attended to the distractor. The authors concluded that aversively conditioned stimuli automatically captured attention, indicating the presence of attentional biases towards threat-related information.

According to Öhman and Mineka (2001) the Fear Module is essential to survival, alerting the organism to threat and preparing the body for evasive or aggressive maneuvers. While this fear response is normally protective, excessive fear, or fear in situations that do not pose an objective danger to one’s safety, is maladaptive. Thus, clinical anxiety can be conceptualized as a hyperactivation of a human’s natural fear response (Beck & Clark, 1997; Oatley & Johnson-Laird, 1987; Öhman & Wiens, 2004). A person whose fear response hinders their ability to partake in daily activities, engage in meaningful relationships, and generally enjoy themselves can be diagnosed with an anxiety disorder (Beck & Clark, 1997).

**Attention Bias Modification**

The classic cognitive model of social anxiety disorder emphasizes a theme of increased attentional bias to threat. In comparison to the typical level of attentional bias to threat demonstrated by non-anxious individuals, people with high anxiety (and particularly those with
social anxiety disorder) exhibit increased attentional allocation towards potentially threat-related stimuli (for systematic reviews and meta-analyses on this topic, see Bantin et al., 2016; Bar-Haim et al., 2007; Cisler & Koster, 2010; Clauss et al., 2022; Dudeney et al., 2015; Goodwin et al., 2017; Günther et al., 2021; Mathews & MacLeod, 1994; Ruiz-Caballero & Bermúdez, 1997; Shi et al., 2022). The wealth of evidence supporting increased attentional bias to threat in anxiety combined with guidance from well-reputed cognitive theories led researchers to develop Attention Bias Modification, a new approach to treating anxiety disorders.

Attention Bias Modification is a computer-delivered treatment for anxiety disorders in which patients are trained to direct their attention to neutral stimuli while simultaneously being exposed to threat-related non-targets (Schmidt et al., 2009). Attention Bias Modification is commonly implemented using a dot-probe paradigm (MacLeod et al., 1986), in which two stimuli, one neutral and one threatening, are briefly presented side-by-side on the patient’s computer screen. The stimuli are then replaced by a blank screen and a single dot (sometimes an “X” or a similar mark) on one side of the screen, replacing either the neutral or the threatening stimulus. The patient is then instructed to identify the location of the dot. The expectation for non-anxious individuals completing this sort of task is that they should respond equally quickly regardless of whether the dot replaces the neutral or the threatening stimulus. In contrast, studies show that individuals with high anxiety tend to respond more quickly on trials where the dot was in the same location as the threatening stimuli, suggesting that the individual was already fixating on that location (Bantin et al., 2016; Cisler & Koster, 2010; Mathews & MacLeod, 1994; Ruiz-Caballero & Bermúdez, 1997). In the dot-probe paradigm used in Attention Bias Modification treatment, the target dot is always paired with the neutral stimulus location, promoting increased attention towards the neutral stimulus and discouraging attending to the
threatening stimulus. By exposing patients to repeated trials, Attention Bias Modification aims to weaken the patient’s automatic perception of threat, thereby interrupting the self-perpetuating cycle of anxiety.

The development of Attention Bias Modification signaled a turning point in the study of attention in anxiety. Attention Bias Modification promised a relatively brief, targeted approach to treating anxiety disorders that could be implemented on a large scale with little burden on the clinician (Amir et al., 2009a; Schmidt et al., 2009). Furthermore, Attention Bias Modification served as a proof of concept by affording researchers the opportunity to test a direct causal relationship between attentional biases and anxiety: if it was found that reducing attentional bias to threat could effectively treat anxiety symptoms, it would support the longstanding theory that attentional bias to threat causes and maintains anxiety. Initial outcomes were promising, and studies found Attention Bias Modification was associated with significant reductions in anxiety (Amir et al., 2009a, 2009b; Beard et al., 2011; Brosan et al., 2011; Hakamata et al., 2010; See et al., 2009). However, more recent publications offer a less optimistic view of the benefits of Attention Bias Modification. Most meta-analyses conclude that Attention Bias Modification produces inconsistent results and generates small (and sometimes non-significant) effect sizes for reducing symptoms of anxiety in general and social anxiety specifically (Cristea et al., 2015; Fodor et al., 2020; Hang et al., 2021; Heeren et al., 2015). The small effect sizes and inconsistent results across Attention Bias Modification studies suggest that attentional biases may not directly affect anxiety. Rather, with the overwhelming evidence showing a correlation between attentional biases and anxiety it is likely that one or more factors moderate this relationship.
Attentional Bias to Emotional Faces

Research on attention to emotional faces offers another example of how the relation between attentional bias to threat and anxiety cannot be as simple a correlation as has previously been assumed. Facial expressions hold crucial information for communication, and emotional expressions, as compared to neutral expressions, are believed to be especially important for survival. Emotional expressions offer a quick and effective means of transmitting information about prosocial motives or oncoming danger, and it has been theorized that a specialized neural process promotes attentional capture by emotional stimuli due to their fundamental role in human interactions (Öhman, 2009). Research supports this notion, as studies find that emotional faces are more effective at capturing attention than other types of stimuli, such as fruits (Bindemann et al., 2005) or butterflies (Langton et al., 2008). Furthermore, emotional faces show superior attentional capture as compared to neutral faces, suggesting that it is not simply the presence of facial features, but specifically the emotional expressions that are prioritized in visual processing (Bradley et al., 1997).

Among emotional expressions, angry expressions are traditionally thought to promote greater attentional biases because they convey social threat (Öhman, 2009; Öhman & Mineka, 2001). Indeed, many studies (to name a few, Burra et al., 2016; Krysko & Rutherford, 2009; Lipp et al., 2009; Purcell & Stewart, 2010) have used photographs of actors portraying angry expressions to fill the role of ecologically valid threat stimuli. One of the earliest and most influential papers in this regard is Hansen and Hansen’s (1988) face-in-the-crowd study. The study recruited undergraduate students to complete a visual search task, during which they were presented a 3x3 matrix of photographs taken from the Pictures of Facial Affect (POFA; Ekman & Friesen, 1976) stimulus set. The photographs in the matrix varied by trial, with some trials
depicting the same emotional faces (either angry, happy, or neutral) across all the photographs and other trials including a single discrepant emotion (either angry or happy). After some time, the photograph array was replaced with a blank screen and participants were instructed to indicate, as quickly and accurately as possible, whether a discrepant face had been present in the matrix by saying “Yes” or “No” out loud. The results of the study showed angry faces were identified more quickly and more accurately than happy and neutral faces, and Hansen and Hansen coined their seminal finding the Anger Superiority Effect. Notably, much of attentional bias literature finds support for the Anger Superiority Effect among the general population. Hansen and Hansen’s (1988) findings have been replicated in many studies drawing from non-anxious samples (for some examples, see Hahn & Gronlund, 2007; Horstmann & Bauland, 2006; Lipp et al., 2009), indicating that for most people angry faces generally attract attention more effectively than other emotional faces. Thus, the Anger Superiority Effect supports the Fear Module and falls in line with the prevailing evolutionary theories that stress the importance of attending to threat-related information.

Additionally, some researchers have cited concerns regarding the Anger Superiority Effect itself. Recent meta-analyses shed light on inconsistent results found across earlier studies investigating attentional biases to angry faces, indicating the Anger Superiority Effect may not be as universal as initially believed (Gong & Smart, 2021; Liu et al., 2021; Nummenmaa & Calvo, 2015). Some authors have pointed to faulty methodology as a potential source of these inconsistencies (for methodological reviews, see Becker et al., 2011; Becker & Rheem, 2020; Frischen et al., 2008). The first critiques of this sort were directed at the original face-in-the-crowd study; less than 10 years after Hansen and Hansen published their paper, Purcell et al. (1996) published an article critiquing the methodology of the seminal study. Purcell et al. argued
that dark spots on the angry face stimuli (which were unintentionally created when the researchers were editing their stimuli) used in the 1988 experiment likely drew the attention of the participants more successfully than the emotions depicted by the faces, thereby creating a pseudo-Anger Superiority Effect. In replicating the original Anger Superiority Effect study using an unaltered stimulus set, Purcell and colleagues found that happy faces were more successful at attentional capture than angry faces. A growing body of visual search literature (e.g., Bucher & Voss, 2019; Horstmann et al., 2012; Horstmann & Becker, 2020; Öhman et al., 2010) supports this competing hypothesis, aptly named the Happiness Superiority Effect (Juth et al., 2005). As happy faces do not traditionally connote social threat, superior attentional capture by happy faces does not align with the Fear Module (which implies that angry faces capture attention more readily). In turn, this would suggest that the Fear Module is likely more complex than previously assumed, meaning that the relationship between attentional bias to threat and anxiety may be moderated by external factors.

**Factors Affecting Attentional Bias to Threat in Individuals with Social Anxiety**

The unexpected findings from Attention Bias Modification studies and the inconsistent support for the Anger Superiority Effect (as well as the possible existence of a Happiness Superiority Effect) imply that the effect of attentional bias to threat on anxiety is moderated by a number of other factors. In order to adequately address social anxiety disorder symptoms, it is necessary to investigate the roles of additional explanatory factors. The following sections will explore possible moderators, including emotion, perceptual load, and time on-task.

**Emotion**

Drawing from the cognitive theories of increased attentional bias to threat in anxiety, it is expected that individuals with high social anxiety will experience greater attentional bias to
angry faces as compared to non-anxious individuals. A number of studies support this hypothesis (Ashwin et al., 2012; Bar-Haim et al., 2007; Berggren & Eimer, 2020; Bradley et al., 1999; Gilboa-Schechtman et al., 1999). However, attentional biases to faces in anxious populations appear to be more complex. An important finding in this regard is that people with high levels of social anxiety are more likely to attribute negative valence to neutral face stimuli as compared to non-anxious groups (Cooney et al., 2006; Winton et al., 1995). In one study, participants completed an emotion identification task using ambiguous, digitally morphed faces from the POFA series. It was found that high social anxiety individuals categorized more faces as fearful than low social anxiety participants (Richards et al., 2002). The increased perception of negative emotion in the presence of neutral information supports cognitive theories of anxiety. Also, fearful expressions have been conceptualized as an ambiguous indication of threat; whereas angry expressions are indicative of direct social aggression, fear represents an indirect potential danger (Eimer & Kiss, 2007).

As previously discussed, the lack of evidence for a strong Anger Superiority Effect is an indicator of potential moderators on the effect of attentional bias to threat on social anxiety disorder. Furthermore, the conflicting findings supporting the Anger Superiority Effect and Happiness Superiority Effect likely indicate a complex relationship between the emotional expressions depicted by task-irrelevant distractors and attention. It thus stands to reason emotional expressions may change the way attentional biases to threat are expressed in highly anxious individuals.

**Perceptual Load**

As discussed earlier, perceptual load theory (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994) explains variable distractibility during visual search at high versus low levels of
scene complexity; visual search under conditions of greater complexity (high load) is less susceptible to task-irrelevant stimuli than visual search of simple scenes (low load). Therefore, it follows that attentional biases to threat will be more evident at low load as compared to high load. However, studies find that high-anxiety individuals demonstrate greater attentional capture by task-irrelevant threat stimuli at high load.

This finding is explained by Eysenck et al.’s (2007) Attentional Control Theory, which proposes that anxiety reduces inhibitory top-down control on attentional processes. Since top-down processes are inhibited, bottom-up processes (which are attuned to orienting towards threat, per the Fear Module) have greater influence over attentional guidance. Attentional Control Theory also suggests that goal-oriented attention is further impaired when overall processing demands are increased, such as under high load conditions. In this way, the inhibited top-down control caused by anxiety increases attentional bias to threat at high load. This effect appears to be unique to individuals with high anxiety, as among the general population even highly distracting stimuli (such as cartoon characters) fail to capture attention at high load (Forster & Lavie, 2008).

The Attentional Control Theory is illustrated by Soares et al.’s (2015) study. The researchers conducted a letter search task (a variation of the visual search task) in which participants were asked to identify a target letter (either N or X) from within a six-letter circular array. At high load, all the non-target letters in the array were different (randomly selected from G, H, J, S, K, and Y) while in the low load condition all non-targets were the letter “O”, the assumption being that the multiple complex letters would present a higher perceptual load to participants than copies of a single simple letter. On each trial, a task-irrelevant picture of a face expressing an angry, disgusted, happy, or neutral expression appeared on either the right or left
side of the circular array. The study found that individuals with high social anxiety ratings displayed greater RTs than individuals with low social anxiety ratings, indicating greater attentional bias towards facial stimuli in those with high social anxiety.

An important finding of the Soares et al. (2015) study was that the high socially anxious group displayed greater attentional bias to angry faces, but only at high load. At low load, there was no difference in attentional bias to threatening faces. It is therefore possible that high anxiety individuals do exhibit an Anger Superiority Effect, but only under high load conditions. Rather than either emotion or perceptual load independently moderating attentional biases in anxiety, the results of the Soares et al. study point to an interaction between emotion and load being the moderating factor.

**Time On-Task**

In contradiction to theories in line with the Fear Module, a number of studies have found avoidance to be a common symptom of anxiety disorders and is particularly important to better understanding social anxiety disorder (Chen et al., 2002; Heuer et al., 2007). It is hypothesized that avoidance functions as a form of self-regulation, allowing a person to feel less fear and anxiety despite potential threat in the environment. While this strategy offers short-term relief from anxiety, the result is a lack of confrontation with the perceived threat. Since avoidance prevents individuals from disproving the severity of the perceived threat, they are unable to habituate (Clark, 1999).

In an effort to integrate the seemingly contradictory theories of increased attentional bias to threat and avoidance in those with anxiety, the hypervigilance-avoidance theory suggests that individuals with anxiety disorders will first direct their attention towards threat-related stimuli, and then engage in cognitive avoidance, which impedes their ability to objectively evaluate the
apparent threat and thus maintains the disorder (Mogg et al., 1997; Mogg et al., 2004). In support of this theory, Vassilopoulos (2005) conducted a study in which participants were exposed to word pairs at two different durations, and found that participants with high social anxiety showed a pattern of hypervigilance followed by avoidance when presented with threat words, while participants with low social anxiety did not show this effect. In accordance with hypervigilance-avoidance theory, another study found electrophysiological evidence supporting early attentional bias to threat and later avoidance in patients with social anxiety disorder (Mueller et al., 2009).

Using eye-tracking software, Schofield et al. (2013) found that while both socially anxious and non-anxious individuals were more likely to initially orient towards emotional faces, non-anxious participants were more likely to keep their gaze on happy faces and to withdraw their attention from angry and fearful faces. Participants with social anxiety, on the other hand, directed their attention less towards all faces over the course of each trial. This suggests that emotion of faces and time on-task may moderate the relation between attentional bias and anxiety together, rather than independently.

**Multilevel Modeling**

The previous section explained how the combined effect of emotion and time on-task acts as a moderator on the relation between attentional biases and social anxiety. Similarly, it has previously been described how attentional biases and social anxiety are likely moderated by an emotion-perceptual load interaction. It can therefore be extrapolated that the interaction between emotion, perceptual load, and time on-task will likely affect the way in which attentional biases and social anxiety are related. To adequately examine these complex interactions, it is necessary to use multilevel modeling techniques.
Multilevel modeling (MLM), sometimes referred to as hierarchical linear modeling (HLM), is an extension of regression analyses that is uniquely suited to analyzing nested data sets (Tabachnick & Fidell, 2007). The term “nested data” refers to points of information that exist within a larger group, and it is assumed that the data points nested within a single group will be more similar to one another than data points selected from multiple groups. Though more commonly employed when analyzing individuals nested within groups (e.g., students nested within classes, patients nested within hospitals), MLM may be used to assess within-participant repeated measures data as well. Some researchers argue that MLM should, in fact, be used to analyze repeated measures data and that failing to account for its nested structure may lead to inaccurate statistical outcomes. For example, in an attentional study for which participants are asked to complete multiple trials of the same task, each trial would constitute a single data point nested within a participant. It is likely that each participant exhibits a response style that is more consistent with their own responding than with the responding style of another participant. In other words, repeated measures data are dependent on the participants from whom they are collected.

Previous studies investigating attentional biases primarily used the repeated measures analysis of variance (ANOVA) to analyze trial-level data (e.g., Fenske & Eastwood, 2003; Gupta et al., 2016; O’Toole et al., 2011; Yates et al., 2010). The ANOVA is likely the preferred analytical tool for these types of studies because it is relatively simple to perform and provides a useful summary of the differences between conditions in a data set (Whelan, 2008). However, there are several important limitations to using ANOVAs to assess repeated measures data. Notably, an assumption of the ANOVA is that samples must be independent of one another. As
described above, repeated measures data, which constitutes nested data, violates the assumption of independence, meaning that results obtained through ANOVA will not be meaningful.

Another benefit of MLM over the ANOVA in analyzing attentional biases is that MLM offers a way to investigate performance changes on a trial-by-trial basis. ANOVAs require the aggregating of data across trials, and as a result changes in reaction times from one trial to the next are eliminated. More generally, it has been suggested that attentional biases in and of themselves are a fluctuating phenomenon, exhibiting periodic bursts over the course of an attentional task (Zvielli et al., 2015). Furthermore, given the inherent temporal instability of attentional biases, data aggregation offers an incomplete view of the attentional processes over time and can lead to substantial reliability issues across studies (Rodebaugh et al., 2016).

It should also be noted that MLM is adept at performing analyses accurately in the presence of missing data (Lachaud & Renaud, 2011; Tabachnick & Fidell, 2007). Standard procedure for analyzing attentional task data includes removing trials in which the participant answered incorrectly, which guarantees that some data points will be missing from the dataset. While traditional analyses offer methods of managing missing data, these require complex extrapolation procedures and there is a greater risk of generating unexpected statistical outcomes (Lachaud & Renaud, 2011).

**Statement of the Problem**

Popular cognitive theories suggest that a major factor in causing and maintaining anxiety is a pattern of increased attention directed towards threat-related information. These theories are supported by a wealth of empirical evidence showing people with high anxiety exhibit faster reaction times when presented with threat-related stimuli as compared to people with low anxiety (Bantin et al., 2016; Bar-Haim et al., 2007; Cisler & Koster, 2010; Clauss et al., 2022; Dudeney
et al., 2015; Goodwin et al., 2017; Günther et al., 2021; Mathews & MacLeod, 1994; Ruiz-Caballero & Bermúdez, 1997; Shi et al., 2022). However, inconsistencies in the attentional bias to threat literature suggests that attentional biases may not have a direct relation with anxiety. Instead, it is likely that other factors, including emotion, perceptual load, and time-on task, affect this correlation. To examine the complex interactions between these variables, it is necessary to use statistical techniques that can adequately account for temporal fluctuations in attentional biases from one trial to the next. Multilevel modeling (MLM) offers a method of analyzing changes over time without the data loss associated with mean aggregation (Gade et al., 2022).

The proposed study builds upon existing research in this area. Theodorou et al. (2021) similarly conducted a letter search task to investigate attentional biases to angry and neutral faces, as well as threat-related and neutral non-facial objects, at high and low perceptual load conditions in a sample of college students with either high or low levels of social anxiety. The authors found that participants with low social anxiety demonstrated greater attentional bias to threat-related objects (i.e., guns) whereas individuals with high social anxiety were equally attentive to facial and non-facial sources of threat, indicating an overall increased attentional bias to threat in those with high social anxiety. The proposed study expands Theodorou et al.’s research by considering attentional biases to fearful (ambiguous threat) and happy (positive) faces in addition to angry (unambiguous threat) and neutral faces. The authors also noted that only in the high social anxiety group, threatening faces were associated with slower reaction times than threatening objects (although this finding was non-significant), which could indicate a possible attentional bias specific to threatening faces for individuals with high social anxiety. By using MLM to analyze trial-by-trial changes in reaction times, the proposed study will explore the effects of time on-task on the relation between social anxiety, emotion, perceptual load, and
attentional biases, which may provide greater insight into the specificity of attentional biases in social anxiety.

MLM has been used by previous studies to investigate changes in attentional biases over time. Notably, McGlade et al. (2020) used MLM to investigate how social anxiety affected trial-by-trial changes in reaction time in the presence of threatening faces. The present study seeks to expand on this by also varying the perceptual load conditions in the letter search task. Additionally, one of the limitations identified by McGlade et al. in their study was that all participants in the population they had sampled had a comorbid depression diagnosis, which could make the results of the study less generalizable to individuals with only social anxiety disorder. For improved generalizability, the proposed study sampled a non-clinical population and had no inclusion or exclusion criteria for participants.

Thus, the proposed study will use MLM to analyze trial-by-trial reaction time changes on a letter search task in order to investigate how attentional biases to distractor faces are affected by 1) social anxiety (high or low, based on mean SPAI-23 scores), 2) emotion type (angry, fearful, happy, or neutral), 3) perceptual load (high or low), and 4) time on-task. It is hypothesized that attentional biases, as measured by reaction times, will be dependent on the interactions between all of these factors. Specifically, it is predicted that participants with high social anxiety scores will generally demonstrate increased attentional bias for threat stimuli as compared to participants with low social anxiety scores. This difference is expected to be especially evident in angry and fearful face trials at high load. Additionally, this effect is expected to be more pronounced in the early trials of the letter search task and may diminish, or disappear entirely, in later trials.
Method

Participants

Participants were 157 undergraduate students at Virginia Commonwealth University. Students were recruited from an Introduction to Psychology class and received course credit in return for their participation in the study. There were no a priori selection criteria for participants. All participants provided informed consent prior to participating in the study and the study took approximately 40 minutes in total to complete. The participants in the sample were aged 17 to 33 ($M = 19.77$, $SD = 2.39$) and 64.3% of the participants identified as female. The sample was 40.1% White or Caucasian, 23.6% Black or African American, 20.4% Asian, and 15.9% other. Additionally, 9.6% of participants identified as Hispanic. For a complete demographic breakdown by emotion condition, see Table 1 below.

Table 1

Participant Demographics

<table>
<thead>
<tr>
<th>Emotion Group</th>
<th>Angry</th>
<th>Happy</th>
<th>Fearful</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Participants</td>
<td>62</td>
<td>46</td>
<td>49</td>
<td>157</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>36</td>
<td>29</td>
<td>36</td>
<td>101</td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>17</td>
<td>13</td>
<td>56</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Range</td>
<td>17-33</td>
<td>17-25</td>
<td>18-28</td>
<td>17-33</td>
</tr>
<tr>
<td>Mean Age</td>
<td>19.50</td>
<td>19.26</td>
<td>20.55</td>
<td>19.77</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>11</td>
<td>6</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td>Black/African American</td>
<td>11</td>
<td>16</td>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>Hispanic</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>30</td>
<td>13</td>
<td>20</td>
<td>63</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
<td>11</td>
<td>4</td>
<td>25</td>
</tr>
</tbody>
</table>

2 Recruitment and participation in this study was completed prior to the COVID-19 pandemic.
Measures and Materials

**SPAI-23**

The Social Phobia and Anxiety Inventory-23 (SPAI-23; Roberson-Nay et al., 2007) is a 23-item self-report inventory assessing social phobia. It serves as a brief alternative to the full-length SPAI (Turner et al., 1989) and has been validated as an effective tool to measure social anxiety among both clinical and non-clinical college student populations from the same geographic region as the one being sampled for the present study. The present study will use SPAI-23 scores to indicate each participant’s level of social anxiety.

**Pert-96**

The Pert-96 database supplies high quality photographs of male and female actors of a variety of ages and races that have been shown to clearly demonstrate specific emotions (Gur et al., 2002). The present study used 16 unique pictures of happy, angry, fearful, and neutral faces (64 faces total) from the Pert-96 database. Half of the faces used were male and half were female. The faces were presented in a randomized order.

**Letter Search Task**

**Design**

For each trial, the computer screen displayed a six-letter circular array (the letters were white against a black background) comprising one randomly selected target letter (with 50% of trials using “X” and 50% using “Z”) and five nontargets. Nontargets varied by perceptual load condition; high perceptual load trials presented five different letters (H, J, L, W, and Y) arranged in a random order, with equal probability of appearing in any of the six positions along the circular array. Nontargets in low perceptual load trials were five identical dots. The perceptual load condition was varied by block, with 50% of blocks presenting a high perceptual load and
50% presenting a low perceptual load. Each visual array was presented for 100ms before disappearing, at which point participants were allowed 2000ms to select a response; participants were instructed to press the “1” key to select “X” and they were instructed to press the “2” key to select “Z”. Participant reaction times were recorded in milliseconds by the computer throughout the study.

Task-irrelevant distractors appeared in the center of the circular array in 20% of trials (see Appendix A). The remaining 80% of the letter search trials did not include a distractor in order to prevent habituation (Forster & Lavie, 2007, 2008; Yates et al., 2010). Distractors would either be neutral (50% of blocks) or emotional (50% of blocks). The type of emotion depicted by the emotional distractors was determined by the participant’s pseudorandomly assigned group: angry, happy, or fearful. Each participant completed one 160-trial block of each combination of emotionality (emotional or neutral) and load (high or low) for a total of four blocks (640 trials). Blocks were counterbalanced across participants to reduce any order effects. See Tables 2 and 3 below for a visual representation of block orders and condition breakdown.

Table 2

<table>
<thead>
<tr>
<th>Order</th>
<th>Block 1 (Trials 1-160)</th>
<th>Block 2 (Trials 161-320)</th>
<th>Block 3 (Trials 321-480)</th>
<th>Block 4 (Trials 481-640)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High load Emotional distractors</td>
<td>Low load Emotional distractors</td>
<td>High load Neutral distractors</td>
<td>Low load Neutral distractors</td>
</tr>
<tr>
<td>B</td>
<td>Low load Emotional distractors</td>
<td>High load Neutral distractors</td>
<td>Low load Neutral distractors</td>
<td>High load Emotional distractors</td>
</tr>
<tr>
<td>C</td>
<td>High load Neutral distractors</td>
<td>Low load Neutral distractors</td>
<td>High load Emotional distractors</td>
<td>Low load Emotional distractors</td>
</tr>
<tr>
<td>D</td>
<td>Low load Neutral distractors</td>
<td>High load Emotional distractors</td>
<td>Low load Neutral distractors</td>
<td>High load Neutral distractors</td>
</tr>
</tbody>
</table>
Distractors were only present in 20% of trials within each block.

**Table 3**

*Conditions in the Letter Search Task*

<table>
<thead>
<tr>
<th>Face Emotionality</th>
<th>Number of Trials per Participant</th>
<th>Trial Condition</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High Perceptual Load</td>
<td>Low Perceptual Load</td>
</tr>
<tr>
<td>Emotional</td>
<td>32</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>Neutral</td>
<td>32</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>None</td>
<td>256</td>
<td>256</td>
<td>512</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>320</strong></td>
<td><strong>320</strong></td>
<td><strong>640</strong></td>
</tr>
</tbody>
</table>

**Procedure**

Attentional biases were measured via computerized letter search task (similar to the one described in Theodorou et al., 2021). For each trial, participants were presented with a visual array and instructed to identify a pre-specified target letter from within the array. Participants were instructed to submit their responses as quickly and accurately as possible while ignoring any distractor stimuli. Each participant completed four 160-trial blocks (640 total trials per participant) with the option of taking a brief break in between blocks (see Appendix B for an example participant instruction sheet).

**Data Preparation**

Prior to the analysis, all trials with reaction times at or below 150ms or ±2.5 SD from each participant’s average RT score were removed from the dataset, as these trials likely reflect unintentional or low effort responses (Theodorou et al., 2021). Trials in which participants inaccurately identified the target letter within the letter search task array (e.g., pressing the “X” key when the correct answer was “Z”) were also excluded. Additionally, participants were removed from the dataset if they had a substantial number of inaccurate or low effort trials, defined as 2.5 SD above the average number of inaccurate or low effort trials within that
participant’s emotion group.\textsuperscript{3} Using this exclusion criteria, two participants from the Happy emotion group and one participant from the Fearful emotion group were suspected of overall low effort due to requiring a significant amount of trials to be removed (2.5 SD above the average number of removed trials for the other participants in the corresponding emotion groups); these participants were excluded from the final dataset. One participant from the Angry emotion group was removed due to not having completed the SPAI. In total, 25.26\% of trials were removed from the dataset, leaving a total of 75,103 trials across 153 participants in the analyses (see Table 4 for more details). The amount of data removed from the final analyses is in line with quantities reported in the literature (e.g., Forster & Lavie, 2007; Forster & Lavie, 2008; Theodorou et al., 2021).

\textsuperscript{3} Removing trials in which participants inaccurately identified the target letter (e.g., pressing the “x” key when there was no “x” present in the visual array) and removing trials that are believed to reflect low participant effort (e.g., pressing the “x” key so quickly that it is unlikely that the participant had time to actually process the visual array) is standard practice in reaction time trials.
**Table 4**

**Data Preparation**

<table>
<thead>
<tr>
<th></th>
<th>Angry # (% of initial)</th>
<th>Happy # (% of initial)</th>
<th>Fearful # (% of initial)</th>
<th>Total # (% of initial)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Participants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>62</td>
<td>46</td>
<td>49</td>
<td>157</td>
</tr>
<tr>
<td>Removed</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Final</td>
<td>61</td>
<td>44</td>
<td>48</td>
<td>153</td>
</tr>
<tr>
<td><strong>Trials</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>39680</td>
<td>29440</td>
<td>31360</td>
<td>100480</td>
</tr>
<tr>
<td>Removed due to participant exclusion</td>
<td>640 (1.61%)</td>
<td>1280 (4.35%)</td>
<td>640 (2.04%)</td>
<td>2560 (2.55%)</td>
</tr>
<tr>
<td>Removed due to inaccuracy</td>
<td>7729 (19.48%)</td>
<td>5954 (20.22%)</td>
<td>5831 (18.59%)</td>
<td>19514 (19.42%)</td>
</tr>
<tr>
<td>Removed due to low effort</td>
<td>1225 (3.09%)</td>
<td>980 (3.33%)</td>
<td>1098 (3.50%)</td>
<td>3303 (3.29%)</td>
</tr>
<tr>
<td>Total removed</td>
<td>9594 (24.18%)</td>
<td>8214 (27.90%)</td>
<td>7569 (24.14%)</td>
<td>25377 (25.26%)</td>
</tr>
<tr>
<td>Final</td>
<td>30086</td>
<td>21226</td>
<td>23791</td>
<td>75103</td>
</tr>
</tbody>
</table>

**Power Analysis**

At present, there are very few approaches to calculating power for multilevel statistics, and the few that exist do not provide sufficiently interpretable results for use in the present paper.\(^4\) There exist some vague rules of thumb for assessing power in MLM, such as Kreft and de Leeuw’s (1998) well known suggestion that group sizes “should not be too small.” Therefore, rather than directly calculating power, a proxy calculation was used; a very conservative estimate of power can be determined by conducting multiple single-level power analyses for each independent variable used in the final multilevel model. As discussed previously, the analysis of variance (ANOVA) is commonly used to assess attentional biases in emotional face studies. As such, ANOVAs were used as proxy power analyses. It should be noted that this is not

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\(^4\) Power analysis for this paper was attempted using MLPowSim (Browne et al., 2009), Optimal Design Software (Spybrook et al., 2011), and PINT (Snijders & Bosker, 1993). The outputs produced by these programs did not meaningfully contribute to this author’s the understanding of whether the present study had sufficient data points to limit the possibility of Type II error. These outputs are therefore not included in this paper.
mathematically equivalent to conducting an MLM power analysis; however, given that the power of the MLM is higher than the power of the ANOVA, it can be assumed that if the ANOVA-based analysis produces sufficient power, then the MLM will as well.

Power analyses were conducted using G*Power (Faul et al., 2009). All power analyses were conducted at 0.80 power and \( \alpha = .05 \). The first analysis indicated that a minimum sample size of 969 would be necessary to detect a small effect of emotion group (i.e., angry, happy, fearful) on RT. In this analysis, the sample size represents the number of accurate, effortful trials with distractor faces present completed by participants in all three emotion groups combined. After data filtering, there were 14901 trials remaining in the final dataset. Therefore, there is more than sufficient power to detect a small effect of emotion group on RT. The second, third, and fourth analyses indicated that a sample size of 788 would be necessary to detect a small effect of perceptual load (high or low) on RT, a small effect of face emotionality (emotional or neutral) on RT, and a small effect of social anxiety severity (high social anxiety vs low social anxiety) on RT. The 14901 trials in the final dataset offer more than sufficient power to detect small effects of load, emotionality, and social anxiety on RT.

**Data Analysis Strategy**

Multilevel modeling, using two-level multilevel growth models, was used to assess change in participants’ reaction times as a function of the independent variables. Reaction time (RT), measured in milliseconds (ms), was the dependent variable in all analyses. The two-level models were set up with trials (level 1) nested within participants (level 2). Trial-level independent variables included perceptual load (high or low), face emotionality (emotional or neutral), and trial number (1-160). Social anxiety severity was included as a participant-level independent variable. To increase the predicting power of the statistical analysis within a non-
clinical population, social anxiety severity was converted into a dichotomous variable (high social anxiety vs low social anxiety). The mean of all participants was calculated (SPAI $M = 25.42$) and participants were determined to have high social anxiety if their SPAI score was higher than or equal to the mean (SPAI $\geq 25.42$) while participants with SPAI scores lower than the mean (SPAI $< 25.42$) were identified as having low social anxiety. Analyses tested the effect of social anxiety severity on the slope of attentional capture (via RTs over time) as a function of perceptual load and face emotionality, with low load and neutral faces serving as the reference groups, respectively. Given that there was no participant overlap between the angry, happy, and fearful emotion groups, independent multilevel models for each emotion group were constructed. Following the repeated measures example described in Field and Wright (2011), multilevel models were created using a build-up strategy wherein variables are added, one at a time, to a baseline model to see if they improve model fit (see Appendix C for a full comparison of fit statistics). The baseline was established using random intercepts and no fixed effects, defined as the following:

Baseline, Level 1:

$$\text{RT}_{ij} = \beta_{0j} + e_{ij}$$

Baseline, Level 2:

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

where $i$ represents trials and $j$ represents participants. The reaction time of a given participant $j$ in a given trial $i$ is defined by the term $\text{RT}_{ij}$. The term $\beta_{0j}$ represents participant $j$’s average reaction time across trials. The term $e_{ij}$ represents random error at the trial level, which is

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5 Participants in the present study’s sample reported relatively low SPAI-23 scores, even compared to similar nonclinical samples as presented in Roberson-Nay et al. (2007). It was determined that in order to increase the chance of detecting an effect of social anxiety, SPAI-23 scores would be converted into a binary variable. This also improves ease of interpretation, given all other level one variables are also binary.
the difference between participant \( j \)’s reaction time in trial \( i \) and participant \( j \)’s mean reaction time across trials. The term \( \gamma_{00} \) represents the grand mean of reaction times across all participants. The term \( u_{0j} \) represents the random error for participant \( j \), which can be interpreted as individual variation.

The baseline was then built upon by gradually adding independent variables to the model. The “best fit” model for each emotion group was determined to be the one which incorporated the most predictors while still contributing a statistically significant (at to 0.05 alpha level) increase in the -2 log likelihood during chi-square distribution calculations (please see Appendix C tables for all model fit comparisons). Maximum likelihood estimations were used to allow for direct comparisons between models using chi-square analysis. The models were assessed for linearity, normality of the residuals, homoscedasticity, and multicollinearity. All multilevel models were fit using the ‘nlme’ package (Pinheiro et al., 2023) in R version 4.2.2 (R Core Team, 2022).

**Results**

**Main Effects**

The main effects of perceptual load and trial number were significant in all emotion groups. RTs were on average greater in high load trials than they were in low load trials, indicating participants reacted more slowly in trials where the visual array contained five different letters, and reacted more quickly in trials where the visual array contained five identical dots (Angry emotion group: \( b = 229.75, SE = 33.27, t(5760) = 6.91, p < 0.001 \), Happy emotion group: \( b = 210.98, SE = 27.23, t(4268) = , p < 0.001 \), Fearful emotion group: \( b = 219.38, SE = 14.28, t(4692) = 15.36, p < 0.001 \)). These results align with Load Theory and indicate the principal manipulation used in this study was effective, allowing me to proceed with the analysis.
As such, we can proceed to interpret the remaining results with some degree of confidence. RTs were found to change over the course of the study, with participants demonstrating quicker reactions in later trials, Angry emotion group: $b = -0.14$, $SE = 0.039$, $t(5760) = -3.57$, $p < 0.001$ (Figure 1A), Happy emotion group: $b = -0.091$, $SE = 0.040$, $t(4268) = -2.28$, $p = 0.023$ (Figure 1B), Fearful emotion group: $b = -0.12$, $SE = 0.025$, $t(4692) = -4.78$, $p < 0.001$ (Figure 1C).

Results revealed a main effect of social anxiety within the angry emotion group, $b = -55.83$, $SE = 22.49$, $t(5760) = -2.48$, $p = 0.016$, such that participants with high social anxiety demonstrated quicker RTs on average than participants with low social anxiety. This main effect of social anxiety was found only in the angry emotion group. Within the happy emotion group, social anxiety did not have a significant main effect, $b = 15.45$, $SE = 23.83$, $t(42) = 0.65$, $p = 0.52$.

Similarly, when constructing the model for the fearful face group, I found that including social anxiety as a standalone predictor variable did not significantly improve model fit, $\chi^2(6) = 0.07$, $p = 0.79$. As a result, social anxiety was not included as its own predictor variable in the final model and it can be assumed that social anxiety does not have a significant main effect on RTs in the fearful face condition. It is important to note that the main effects of load and trial number were qualified by several interaction effects, which are described in the sections below.
Figure 1A

*Change in Reaction Times across Trials in the Angry Face Condition*

Note. The main effect of trial number was significant at the 0.05 level in the angry emotion condition.
Note. The main effect of trial number was significant at the 0.05 level in the happy emotion condition.
Figure 1C

*Change in Reaction Times across Trials in the Fearful Face Condition*

Note. The main effect of trial number was significant at the 0.05 level in the fearful emotion condition.
Interaction Effects

The angry, happy, and fearful models all showed a significant two-way interaction between load and trial number, Angry: $b = -0.17$, SE = 0.065, $t(5760) = -2.60$, $p = 0.0093$ (Figure 2A), Happy: $b = -0.21$, SE = 0.062, $t(4268) = -3.41$, $p < 0.001$ (Figure 2B), Fearful: $b = -0.11$, SE = 0.038, $t(4692) = -2.82$, $p = 0.0048$ (Figure 2C). These results indicate that in each of the emotional face conditions, participants exhibited faster reaction times as they completed more trials, and the rate at which participants grew faster was steeper in the high load condition compared to the low load condition. The happy emotion group showed a significant three-way interaction between load, emotionality, and trial number, $b = 0.22$, SE = 0.10, $t(4268) = 2.21$, $p = 0.027$ (Figure 3B). This means that within the happy face condition, at high loads participant RTs grew faster at a steeper rate when participants were presented with neutral faces than when participants were presented with happy faces. This effect was not seen in at low loads; in the happy face condition at low loads participants showed reduced RTs across trials at approximately the same rate regardless of whether the distractor face was happy or neutral. This interaction was not significant in the angry emotion group, $b = 0.032$, SE = 0.093, $t(5760) = 0.35$, $p = 0.73$ (Figure 3A), nor was it significant in the fearful emotion group, $b = -0.007$, SE = 0.031, $t(4692) = -0.21$, $p = 0.84$ (Figure 3C). Finally, the fearful emotion group showed a significant three-way interaction between social anxiety, emotionality, and trial number, $b = -0.075$, SE = 0.033, $t(4692) = -2.28$, $p = 0.023$ (Figure 4C). This three-way interaction indicates that within the fearful emotion condition, participants with high social anxiety demonstrated a significantly steeper rate of RT decrease when the letter search task presented fearful distractor faces as compared to neutral distractor faces. Participants with low social anxiety demonstrated approximately the same rate of RT decrease regardless of whether the distractor faces in the
letter search task were fearful or neutral. The three-way interaction between social anxiety, emotionality, and trial number was not significant in the angry emotion group, $b = -0.033$, SE = 0.027, $t(5760) = -1.19$, $p = 0.24$ (Figure 4A). It can be assumed that the three-way Social Anxiety x Emotionality x Trial Number interaction effect was not significant in the happy face group (Figure 4B); the interaction was not included in the happy face model as it was found that including the interaction did not significantly improve model fit, $\chi^2(18) = 2.58$, $p = 0.11$. 
Figure 2A

*Change in Reaction Times across Trials by Load in the Angry Face Condition*

*Note.* The Load x Trial Number interaction effect was significant at the 0.05 level in the angry emotion condition.
Note. The Load x Trial Number interaction effect was significant at the 0.05 level in the happy emotion condition.
Figure 2C

*Note.* The Load x Trial Number interaction effect was significant at the 0.05 level in the fearful emotion condition.
Figure 3A

*Change in Reaction Times across Trials by Load and Emotionality in the Angry Face Condition*

*Note.* The Load x Emotionality x Trial Number interaction effect was *not* significant at the 0.05 level in the angry emotion condition.
Figure 3B

*Note.* The Load x Emotionality x Trial Number interaction effect was significant at the 0.05 level in the happy emotion condition.
Note. The Load x Emotionality x Trial Number interaction effect was not significant at the 0.05 level in the fearful emotion condition.
Note. The Social Anxiety x Emotionality x Trial Number interaction effect was not significant at the 0.05 level in the angry emotion condition.
Figure 4B

*Note.* The Social Anxiety x Emotionality x Trial Number interaction effect was *not* significant at the 0.05 level in the happy emotion condition.
Note. The Social Anxiety x Emotionality x Trial Number interaction effect was significant at the 0.05 level in the fearful emotion condition.
Discussion

The present study sought to expand the understanding of attentional biases to facial stimuli by using MLM to analyze the complex interactions between social anxiety, perceptual load, emotion, and time on-task. Participants completed a simple choice task in which they were asked to identify which of two letters was present within a circular array (i.e., letter search task). In some trials, faces that were unrelated to the primary task appeared in the center of the circular letter array. As such, participants’ reaction times (as measured in milliseconds) in trials with different types of distractor faces could be compared to assess attentional biases.

It was hypothesized that attentional biases towards social threat would be dependent on the interactions between multiple variables, rather than a direct effect of social anxiety as is commonly found in studies that do not use MLM. In line with existing cognitive theories of social anxiety, the present study predicted that there would be a greater attentional bias towards angry and fearful faces (which are associated with social threat) among participants with high social anxiety as compared to those with low social anxiety (Beck & Clark, 1997; Clark & Wells, 1995; Mathews & MacLeod, 1994; Rapee & Heimberg, 1997; Trower & Gilbert, 1989). Additionally, the increased attentional bias towards socially threatening faces was expected to be more evident in high perceptual load trials than in low perceptual load trials (Eysenck et al., 2007; Soares et al., 2015). Furthermore, the effect of social anxiety on attentional biases was expected to be stronger at the start of the study, diminishing as time went on and participants completed more trials.

Effect of Social Anxiety on Attentional Biases to Social Threat

As was predicted, the present study found that social anxiety does moderate the effect of angry and fearful distractor faces on reaction times, supporting this study’s primary hypothesis
that attentional biases are dependent on interactions between multiple variables. It should be noted that although there was a significant main effect of social anxiety in the angry emotion group, there was no significant difference between trials featuring neutral faces versus angry faces. In other words, participants with high social anxiety exhibited faster reaction times than participants with low social anxiety regardless of whether the distractor face was angry or neutral.

At first glance, it may seem that the mere presence of a distractor face led to participants with higher social anxiety responding more quickly than participants with low social anxiety. This aligns with cognitive theories of social anxiety, which propose that people with high social anxiety are more likely to interpret neutral remarks made by others as scrutinizing and indicative of social failure (Beck & Clark, 1997; Clark & Wells, 1995; Mathews & MacLeod, 1994; Rapee & Heimberg, 1997). Empirical evidence from previous studies also supports the theory that people with high social anxiety are more likely than people with low social anxiety to interpret emotionally ambiguous faces, such as neutral faces, as being negatively valenced or even threatening (Cooney et al., 2006; Richards et al., 2002; Winton et al., 1995).

However, the availability of multiple emotion groups allows for another perspective on this finding; the fearful and happy face groups did not find a significant main effect of social anxiety. All of the emotion conditions were identical in their design, and they all featured neutral face trials. The only difference between the conditions were the emotional face trials, in which the distractor was depicted either an angry, fearful, or happy face. Therefore, it stands to reason that the key variable behind the significant main effect of social anxiety in the angry face condition is, in fact, the angry face trials. In other words, social anxiety affects reaction times, but only in the presence of angry faces.
Discrepancy with Evolutionary Theories

It was predicted that the participants who rated themselves as highly socially anxious and who were assigned to the angry or fearful groups would show slower reaction times in emotional face trials. However, the present study found that in both the angry and fearful face conditions, participants with high social anxiety demonstrated faster reaction times than participants with low social anxiety. Slower reaction times on a letter search task are generally believed to reflect greater attentional capture by task-irrelevant stimuli. Thus, these faster reaction times indicate less attentional capture by distractor faces.

The finding that participants with high social anxiety exhibit less attentional capture by socially threatening stimuli challenges evolutionary theories, such as the Fear Module (Öhman & Mineka, 2001). The Fear Module describes an underlying neural circuitry that preferentially and automatically draws one’s attention to environmental threats regardless of voluntary task engagement. Consequently, the present study’s finding challenges the Anger Superiority Effect (Hansen & Hansen, 1988), which identifies angry faces as a type of environmental threat that would trigger the Fear Module. The Anger Superiority Effect is supported by a large number of previous studies which find greater attentional capture by angry faces among the general population (e.g., Hahn & Gronlund, 2007; Horstmann & Bauland, 2006; Lipp et al., 2009). Additionally, a wealth of existing literature reports a comparatively stronger Anger Superiority Effect among people with high social anxiety (Ashwin et al., 2012; Bar-Haim et al., 2007; Berggren & Eimer, 2020; Bradley et al., 1999; Gilboa-Schechtman et al., 1999). However, more recent research highlights methodological issues in previous Anger Superiority Effect studies, bringing the universality of the effect into question (Becker et al., 2011; Becker & Rheem, 2020; Frischen et al., 2008; Gong & Smart, 2021; Liu et al., 2021; Nummenmaa & Calvo, 2015).
The discrepancy between the present study’s finding and previous Anger Superiority Effect studies could be attributed to a difference in data analysis techniques. The present study used MLM to analyze trial-by-trial fluctuations in reaction times across trials, whereas much of the research on the Anger Superiority Effect uses methods such as the ANOVA. Commonly used statistical analyses, like the ANOVA, aggregate data across trials and therefore may eliminate the ability to detect certain effects (Rodebaugh et al., 2016; Zvielli et al., 2015). By using MLM to isolate variables such as time on-task and individual differences, it is possible that the present study was able to reveal previously hidden effects, via a phenomenon known as Simpson’s Paradox (Kievit et al., 2013). Previous Anger Superiority Effect studies were unable to account for individual factors and time on-task in the way that MLM allowed for in the present study. As a result, it is possible that those previous studies discovered one type of group effect (the Anger Superiority Effect), that was reversed when those factors were removed (reduced attentional bias towards angry and fearful faces in people with high social anxiety).

**Evidence for Threat Avoidance**

While the present study’s finding that social anxiety reduces attentional bias towards threat might appear to oppose evolutionary theories like the Fear Module and the Anger Superiority Effect, these are not necessarily contradictory. Following an initial attentional capture, people with high social anxiety may preferentially direct their attention away from threat-related stimuli. This behavior is described as a hypervigilance-avoidance pattern (Mogg et al., 1997; Mogg et al., 2004; Mueller et al., 2009; Vassilopoulos, 2005). Avoidance theories of social anxiety suggest that it is the avoidance of, rather than the attention to, threatening stimuli that perpetuates symptoms. These theories suggest that people with high social anxiety avoid anxiety-provoking stimuli in an attempt to reduce distress in the short term, but their anxiety is
inevitably increased in the long term. This occurs because by avoiding distressing stimuli, people with high social anxiety prevent the extinction of anxiety-related thoughts, behaviors, and physical sensations (Chen et al., 2002; Clark, 1999; Heuer et al., 2007). An increased avoidance of facial distractors in participants with high social anxiety would also explain why Attention Bias Modification, which focuses on training people to direct their attention away from threat-related stimuli (effectively promoting avoidance), has been inconsistent in reducing social anxiety (Cristea et al., 2015; Fodor et al., 2020; Hang et al., 2021; Heeren et al., 2015). Thus, the use of MLM may have allowed the present study to identify avoidance as the key mechanism of perpetuating social anxiety.

**Effect of Time On-Task on Attentional Biases**

It was predicted that using MLM to analyze trial-by-trial changes in reaction times would offer insight on how attentional biases are affected by social anxiety, the perceptual load condition of the trials, and the emotion of the distractor faces present in the trials. In line with predictions, the present study found that the rate at which reaction time improved was dependent on the interactions between the factors listed above.

Broadly, it was found that participants became faster at responding to the letter search task as time went on, as indicated by the significant effect of trial number on reaction times. It is likely that improved reaction times over trials reflect a practice effect; as participants completed more trials of the letter search task, they became more familiar with the task itself and were able to develop techniques to improve their efficiency with completing the task (Mowbray & Rhoades, 1959; Teichner & Krebs, 1974). It is expected that this effect would be more noticeable in high load trials than in low load trials. The high load condition poses more of a challenge than the low load condition, and therefore offers more opportunity for strategy development and
performance improvement. Whereas, for the low load condition, participants are already expected to be close to peak performance at the start of the study and are unlikely to show additional improvement. Thus, it is expected that there would be a substantial improvement in reaction times from the beginning of the study to the end in the high load condition. Conversely, the low load condition is already fairly simple, so there are few improvements that can be made to effectively cut down on reaction times, thus improvements in reaction times would be less evident across trials when compared to high load.

Indeed, the present study found that participants in the angry and fearful emotion groups showed quicker improvements in reaction times across high perceptual load trials than they did across low load trials. However, in the happy emotion group, the interaction between load and trial number was moderated by whether the distractor face was emotional (happy) or non-emotional (neutral). While trials featuring neutral faces showed the expected pattern of quicker responding across high load trials as compared to low load trials, the response times on happy faces trials produced the same improvement over time regardless of the load condition. This result could indicate that despite the high load condition, the happy distractor faces were successful in capturing the attention of participants.

Support for a Happiness Superiority Effect

Attentional capture by happy faces at high load is somewhat unexpected, according to Perceptual Load Theory. Perceptual Load Theory suggests that attentional capture is dependent on cognitive resource availability. Thus, if a person’s cognitive resources are not fully engaged, such as when completing a visually simple (low load) primary task, then they will be automatically reallocated to processing other available information, including task-irrelevant stimuli. If, however, a person’s cognitive resources are fully engaged in attending to a visually
complex (high load) primary task, it is less likely that their attention would be directed towards a task-irrelevant distractor (Lavie, 1995; Lavie et al., 2004; Lavie & Tsal, 1994).

Perceptual Load Theory has been proposed as a general rule for understanding attentional processes, although some researchers have found that certain stimuli may effectively capture attention despite an apparent unavailability of one’s cognitive resources. As previously discussed, the Fear Module suggests that the presence of threatening stimuli would capture attention away from a primary task due to the evolutionary advantage of being made aware of threat in the environment (Öhman & Mineka, 2001). While it is traditionally believed that angry faces are likely to drive attention away from a primary task at high load (Anger Superiority Effect; Hansen & Hansen, 1988), the results of the present study did not indicate this.

The attentional capture by happy faces at high load would, however, support the Happiness Superiority Effect (Juth et al., 2005), which suggests that the evolutionary value of happy faces is strong enough to pull attention away from a primary task. The Happiness Superiority Effect is parallel to the Fear Module, arguing that the evolutionary relevance of happy faces make them more effective at capturing attention than other stimuli. The theory behind the Happiness Superiority Effect suggests it is advantageous to have one’s attention directed away from a primary task and instead directed toward a happy face, even if it is task-irrelevant, as happy faces are signifiers of prosocial motivations. Many studies support the Happiness Superiority Effect (e.g., Bucher & Voss, 2019; Horstmann et al., 2012; Horstmann & Becker, 2020; Öhman et al., 2010), although the research supporting the effect varies. Notably, studies that support a Happiness Superiority Effect often negate the existence of an Anger Superiority Effect, and vice versa. Since both effects are based in opposing evolutionary theories, they are fundamentally incompatible, yet each effect is backed by a sizable body of empirical
evidence. As was previously discussed, the variability in these emotional face studies may be attributed to the use of aggregate statistical techniques in analyzing reaction time data. The present study’s use of MLM allowed for a different perspective on the effect of emotional faces on participants’ reaction times by reducing the interference caused by confounding variables.

Limitations and Recommendations for Future Research

A major limitation of the present study was that the results were based on a non-clinical sample; participants comprised exclusively college students at Virginia Commonwealth University and there were no exclusion criteria. Although some participants presented with higher social anxiety than others, the overall range of social anxiety in the sample was within the expected range for the general public. Much of the previous research that formed the theoretical basis for the present study was conducted with participants who had clinically elevated levels of social anxiety, which may have contributed to some of the unexpected results produced by the present study. This was particularly evident in the happy face condition, which showed that at high load, participants had slower reaction time improvements across happy face trials than across neutral face trials. In a study conducted by Schofield et al. (2013), it was found that the interaction between timing and emotion affects attentional capture. The study showed that initially, people tend to orient towards all types of emotional faces, but as time goes by people with less social anxiety tend to direct their attention more towards happy faces while people with high social anxiety tend to direct their attention away from faces in general. Although the present study did not find any significant effect of social anxiety in the happy face condition, it is possible that participants with clinically high social anxiety would differentiate themselves from participants with low social anxiety by not demonstrating attentional capture in happy face trials. It is recommended that future research consider sampling from populations with diagnosed social
anxiety disorder to more precisely determine how attentional biases are affected by social anxiety in different emotional face conditions. It should also be noted that in an effort to increase the chance of detecting effects of social anxiety, SPAI-23 scores were converted into a binary variable. While this technique increased the chance of detecting effects of social anxiety in the present sample, it may have increased the chance of spurious findings. It is expected that dichotomizing will not be necessary if the present study’s methodology were to be replicated with a clinical sample.

Another limitation of the present study was that responses within the angry, fearful, and happy conditions could not be directly compared, since they were analyzed using discrete multilevel models. Therefore, there is a limited degree to which conclusions about the effect of emotional faces on attentional biases relative to each other can be made. This limitation came about as a result of each participant being assigned to a single emotional face condition. Exposing participants to multiple emotional faces within a single study would allow for direct within-participant comparisons of reaction times. The present study used within-participant comparisons to effectively evaluate the differences between neutral versus emotional face trials, however it was not possible to conduct similar analyses between different emotion groups because they were not varied within participants. The present study was designed such that each participant was exposed to exactly one emotional face (either an angry face, a fearful face, or a happy face) during certain trials. Therefore, combining all three emotional face conditions into one multilevel model would necessitate adding an additional individual-level (level two) variable. Incorporating an additional individual-level variable into the analysis would have reduced the model’s ability to detect effects at the trial-level (level one), which were the main focus of the present study. In a study designed to expose all participants to all available
emotional face conditions (angry, fearful, and happy faces), emotional face type could be incorporated into a multilevel model as a trial-level variable. Thus, these within-participant comparisons would make it possible to determine whether different emotions have different attentional capture capabilities. It is recommended that future study designs incorporate multiple experimental emotion conditions within participants.

Interpreting reaction time data can be done in different ways, which may lead to some variations in outcomes. It is commonly accepted that higher reaction times indicate greater attentional biases towards distractor stimuli, however participants may take more time to identify a target within the visual search array when their mood state changes, such as when they are feeling bored. Anecdotal evidence suggests that college student participants (such as those sampled for this study) become bored when completing lengthy and monotonous tasks (such as 640 trials of a letter search task). In fact, one study found that disengaging from a simple attentional task, particularly at low load, increases one’s sense of boredom and is correlated with reduced performance on the task (Yakobi et al., 2021). To account for the possibility that reaction times may be influenced by participants’ mood or other fluctuating confounds, it is helpful to have an additional source of data by which to gauge attentional biases. One potential source of additional data could be eye fixation. Eye-tracking has been increasingly used in visual attention research to address this exact issue. Clauss et al. (2022) conducted a meta-analysis on eye-tracking studies and found that participants with high social anxiety demonstrated an increased attentional bias towards threat-related stimuli. Conversely, Günther et al. (2021) conducted a similar meta-analysis showing that eye-tracking data aligns with the results of the present study, in that participants with high social anxiety largely directed their attention away from social threat. It is recommended that future studies consider implementing eye-tracking.
technology to increase the certainty with which assumptions about attentional biases can be made. Furthermore, it is recommended that MLM be employed to reduce any interference from confounding variables that may have resulted in the inconsistencies seen in previous research.

**Summary and Implications for Treatment**

The present study used multilevel modeling (MLM) to analyze the effect of social anxiety on trial-by-trial changes in reaction times, as well as how this effect was moderated by perceptual load, different types of task-irrelevant distractor faces, and time on-task. While it was hypothesized that participants with high social anxiety would exhibit higher attentional biases towards socially threatening stimuli, results showed that participants with high social anxiety actually had faster response times in angry and fearful face conditions. This could suggest that the main driving mechanism behind anxiety maintenance in social anxiety is the avoidance of potential sources of social distress (Chen et al., 2002; Clark, 1999; Heuer et al., 2007), rather than an increased attentional bias towards social threat as has been proposed by some traditional cognitive models of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997). It was also found that with fearful faces, participants with high social anxiety became faster at a steeper rate over the course of the study, suggesting that they may have become more avoidant over time, which continues to align with avoidance theory.

Although this study was conducted using a non-clinical college student sample, the findings of this study could still be cautiously interpreted to have some implications for the treatment of social anxiety disorder. Assuming that avoidance is the prime driving force of social anxiety symptoms, it is important to investigate treatments that effectively address avoidance. Exposure therapy, a front-line treatment for anxiety disorders, focuses on encouraging patients to approach anxiety-provoking stimuli (Barlow et al., 2015; Chambless et al., 1997; Garner et al.,
By completing repeated exposure exercises, patients can “test” their expectations for feared scenarios and often discover that they are not as catastrophic as initially believed. Confronting distressing situations also allows patients to build up their ability to cope with distress, which often increases their confidence in taking on similar challenges in the future. In these ways, exposures interrupt the cycle of anxiety that perpetuates anxiety symptoms and patients are able to desensitize to the distressing stimuli, such that the severity of their anxiety response to those stimuli decreases over time. Given that avoidance maintains social anxiety and approaching distressing stimuli can treat anxiety, future research should investigate whether increasing attention towards angry and fearful faces could decrease social anxiety over time.

The results of the present study can be used to inform the future development of novel exposure techniques. In recent years, promising research in the field of Virtual Reality Exposures for Social Anxiety Disorder has found that completing exposures in a virtual reality environment is effective at reducing symptoms of social anxiety disorder (Emmelkamp et al., 2020; Horigome et al., 2020; Wechsler et al., 2019). However when compared to existing treatments for social anxiety disorder, including in vivo exposures or cognitive behavioral therapy, virtual reality exposures have not been found to be consistently more effective at reducing symptoms. The primary advantage of virtual reality exposures over other types of treatment is that the virtual reality environment can be more easily controlled by both the clinician and the patient, allowing for more individualized treatment (Wechsler et al., 2019). This highly controlled virtual environment can be manipulated to encourage more effective attentional capture by socially threatening stimuli. Increased attentional capture by social threats would reduce attentional avoidance and, consequently, enhance the efficacy of the exposures. Therefore, directing
attention towards socially threatening faces in a virtual reality environment may offer new
directions for reducing symptoms in patients with social anxiety disorder.
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https://doi.org/10.1016/S0140-6736(20)30925-9


Appendix A

Example Stimuli

Example neutral face stimuli. The image on the left represents an example of a low load condition in which the participant is meant to find the letter Z. The image on the right represents an example of a high load condition in which the participant is meant to find the letter X.
Appendix B

Participant Instructions

Welcome to the experiment!

This is an experiment on reaction time. Your task is to respond as QUICKLY and ACCURATELY as possible to brief displays.

You will perform on a visual search task. On each of several trials, you will see a display with one letter (target letter X or Z; Example 1) or six letters (X or Z plus five other non-target letters; Example 2) appearing in a circular arrangement around the centre of the screen. Your task is to press a button as QUICKLY and as ACCURATELY as possible identifying which of the two target letters (X or Z) was present in each trial.

Note that in some trials a face will appear at the center of the screen, inside the letter circle. The purpose of the face is to slow you down. Please try to ignore it and respond to the target letter as quickly as possible.

Example 1

Example 2

The letters will appear for 100 ms (very briefly). You will next be given 2 seconds to respond as quickly and accurately as possible. Use the numeric keypad to indicate which target letter appeared:

“1” for “X” using your right hand INDEX finger

“2” for “Z” using your right hand MIDDLE finger

Please guess when not sure. Try to ALWAYS give a response even if not sure.

To continue to the next trail press any key.
It is important that you work as fast as possible while also being as accurate as possible. This is the main purpose of the experiment. We will be recording your reaction time and accuracy scores. Be aware that all displays appear very quickly, so you will need to concentrate.

You will now have some practice blocks (for each possible kind of display) to help familiarize yourself with these instructions.

KEY POINTS:
- Find the “X” or “Z” in the task.
- Ignore the face at the center of the screen when it appears.
- Be as fast as you can while also being as accurate as you can.
Appendix C1

Model Fit Comparison Tables for Angry Face Trials

<table>
<thead>
<tr>
<th>Model</th>
<th>Model df</th>
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<th>-2 log likelihood</th>
<th>Test</th>
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<th>p-value</th>
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<th>Test</th>
<th>L.Ratio</th>
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</table>

* Indicates model is significant at the 0.05 level.
† Indicates best fit model (includes the most variables without overfitting) within series.
## Appendix C2

### Model Fit Comparison Tables for Happy Face Trials

#### Happy Face Models

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#### Happy Faces - Random Slopes Models

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</table>

* Indicates model is significant at the 0.05 level.
† Indicates best fit model (includes the most variables without overfitting) within series.
### Appendix C3

#### Model Fit Comparison Tables for Fearful Face Trials

**Fearful Face Models**

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<td>Model 7 + (Load<em>Emotionality</em>Social Anxiety)</td>
<td>8</td>
<td>62094.1</td>
<td>62158.76</td>
<td>-31037.05</td>
<td>7 vs 8</td>
<td>1.83</td>
<td>0.18</td>
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</table>

**Fearful Faces - Covariance Structure Models**

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>AIC</th>
<th>BIC</th>
<th>-2 log likelihood</th>
<th>Test</th>
<th>L.Ratio</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>Model 2</td>
<td>2</td>
<td>62090.41</td>
<td>62116.27</td>
<td>-31041.20</td>
<td>2 vs 9</td>
<td>32.72</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Model 2 + Autoregressive</td>
<td>9</td>
<td>62059.69</td>
<td>62092.02</td>
<td>-31024.84</td>
<td>2 vs 9</td>
<td>32.72</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Model 2 + Continuous</td>
<td>10</td>
<td>62059.69</td>
<td>62092.02</td>
<td>-31024.84</td>
<td>2 vs 10</td>
<td>32.72</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Autoregressive</td>
<td>11</td>
<td>62059.69</td>
<td>62092.02</td>
<td>-31024.84</td>
<td>2 vs 11</td>
<td>32.72</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Model 2 + Linear Moving Average</td>
<td>12</td>
<td>61981.94</td>
<td>62020.73</td>
<td>-30984.97</td>
<td>2 vs 12</td>
<td>79.75</td>
<td>&lt;0.001 <strong>†</strong></td>
</tr>
</tbody>
</table>

**Fearful Faces - Time Series Variable Models**

<table>
<thead>
<tr>
<th>Model</th>
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<th>AIC</th>
<th>BIC</th>
<th>-2 log likelihood</th>
<th>Test</th>
<th>L.Ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 12</td>
<td>12</td>
<td>61981.94</td>
<td>62020.73</td>
<td>-30984.97</td>
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<td></td>
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<tr>
<td>Model 12 + Trial</td>
<td>13</td>
<td>61859.05</td>
<td>61904.31</td>
<td>-30922.52</td>
<td>12 vs 13</td>
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<td>&lt;0.001 *</td>
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<tr>
<td>Model 13 + Trial*Load</td>
<td>14</td>
<td>61848.78</td>
<td>61900.50</td>
<td>-30916.39</td>
<td>13 vs 14</td>
<td>12.27</td>
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</tr>
<tr>
<td>Model 14 + Trial*Emotionality</td>
<td>15</td>
<td>61850.14</td>
<td>61908.33</td>
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<td>14 vs 15</td>
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<td>Model 15 + Trial*Emotionality</td>
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<td>15 vs 16</td>
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<tr>
<td>Model 16 + Trial<em>Load</em>Emotionality</td>
<td>17</td>
<td>61852.88</td>
<td>61924.00</td>
<td>-30915.44</td>
<td>16 vs 17</td>
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<tr>
<td>Model 17 + Trial*(Load*Emotionality)</td>
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<td>61852.67</td>
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<td>17 vs 18</td>
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<tr>
<td>Model 18 + Trial*(Emotionality*Social Anxiety)</td>
<td>19</td>
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<td>61932.98</td>
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<td>18 vs 19</td>
<td>5.74</td>
<td>0.017 <strong>†</strong></td>
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<tr>
<td>Model 19 + Trial*(Load<em>Emotionality</em>Social Anxiety)</td>
<td>20</td>
<td>61848.18</td>
<td>61938.69</td>
<td>-30910.09</td>
<td>19 vs 20</td>
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</table>

**Fearful Faces - Random Slopes Models**

<table>
<thead>
<tr>
<th>Model</th>
<th>df</th>
<th>AIC</th>
<th>BIC</th>
<th>-2 log likelihood</th>
<th>Test</th>
<th>L.Ratio</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 19</td>
<td>19</td>
<td>61848.93</td>
<td>61932.98</td>
<td>-30911.47</td>
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<tr>
<td>Model 19 + Load</td>
<td>Participant</td>
<td>21</td>
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<td>Model 19 + Emotionality</td>
<td>Participant</td>
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<td>Model 19 + Social Anxiety</td>
<td>Participant</td>
<td>23</td>
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<td>Model 19 + (Load + Emotionality)</td>
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<td>Model 19 + (Load + Social Anxiety)</td>
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<td>25</td>
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<td>56.04</td>
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<tr>
<td>Model 19 + (Emotionality + Social Anxiety)</td>
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<td>61968.54</td>
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<td>Model 19 + (Load + Emotionality + Social Anxiety)</td>
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<td>61803.58</td>
<td>61945.82</td>
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<td>19 vs 27</td>
<td>63.35</td>
</tr>
</tbody>
</table>

* Indicates model is significant at the 0.05 level.
† Indicates best fit model (includes the most variables without overfitting) within series.
Vita

Nina Plotnikov graduated from Barnard College in 2018 with a Bachelor of Arts degree in psychology. In the fall of 2018, she enrolled in the Clinical Psychology Doctoral Degree program at Virginia Commonwealth University in Richmond, Virginia. She received a Master of Science in clinical psychology from VCU in May 2021. After completing her clinical internship at the Lt. Col. Luke J. Weathers, Jr. (Memphis) VA Medical Center, Nina will graduate with her doctorate in Clinical Psychology from VCU in August 2024. She will be starting her postdoctoral residency at the Minneapolis VA Healthcare System with a focus in Serious Mental Illness in August 2024.