Social Anxiety: Understanding the Attentional Bias to Threat

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Statement of Originality

This thesis is submitted to the Australian National University in fulfillment of the degree of Doctor of Philosophy (Clinical Psychology). The work presented in this thesis is original, to the best of my knowledge and belief, except as acknowledged in the text. I hereby declare that I have not submitted the material, either in full or in part, for a degree at the Australian National University or any other institution.

Hannah Lorna Delchau

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Abstract

Biased attention toward threatening facial expressions is an important maintaining and possibly aetiological factor for social anxiety. However, little is known about the underlying mechanisms. To develop our understanding of this threat bias, the relative contributions of top-down attention, bottom-up attention, and selection history were differentiated across four studies. In Study One, the roles of top-down attention, bottom-up attention, and selection history were tested in an unselected sample using a modification of the dot-probe task, in which participants were cued to attend to a happy or angry face on each trial. Results showed that attentional orienting toward facial expressions was not exclusively driven by bottom-up attentional capture as some previous theories suggest; but instead, participants could shift attention toward emotional faces in a top-down manner. This effect was eliminated when the faces were inverted, demonstrating that top-down attention relies on holistic face processing. Study One found no evidence of selection history (i.e., no improvement on repeated trials or blocks of trials in which the task was to orient to the same expression). Study Two tested whether this ability to use top-down attention to orient to emotional faces is impaired for individuals with social anxiety. Using the same task as Study One, Study Two found that participants with higher levels of social anxiety were selectively impaired in attentional shifting toward a cued happy face when it was paired with an angry face, but not when paired with a neutral face. These results indicate that high social anxiety is associated with deficits in top-down control of attention, which are selectively revealed in the presence of non-task-relevant threat. The results of Study Two could be explained by bottom-up attention to threat or a top-down set for threat that could not be overcome by the instruction to attend to a happy face. To test this, Study Three utilised a modified dot-probe task in which participants were presented with an upright face paired with an inverted face (displaying a disgust or neutral expression) and engagement with and disengagement of attention from threatening faces

were measured separately. The task was performed under no, low, and high working-memory load conditions. Since working-memory load draws on the same resources as top-down attention, interference from increasing working-memory load on attentional orienting would point to a role for top-down attention. Social anxiety was not associated with delayed disengagement from threat. However, surprisingly, high social anxiety was associated with an engagement bias *away from* threat, while low social anxiety was associated with a bias *toward* threat. These results were unaffected by the working-memory load manipulation. However, some methodological issues were identified with the study. Study Four overcame these methodological issues by using a paired angry and neutral face under no, low and high working-memory load conditions. Higher levels of social anxiety were associated with increased engagement with threat under no-load, but not under low- and high-load conditions. Thus, this body of research provides evidence that social anxiety is associated with an engagement bias to threat, which is driven by top-down attention.

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Chapter One. Introduction

Rationale for Thesis and Aims

Imagine giving a speech to a room full of people. The crowd looks up at you with a variety of facial expressions; some appear happy and supportive, some neutral, and others appear bored and judgmental. Which faces do you focus on? Research indicates that socially anxious people preferentially allocate attention to threatening facial expressions. Indeed, theoretical and empirical research indicates that this bias is a maintaining, and possibly even an aetiological, factor contributing to social anxiety symptoms (MacLeod & Mathews, 2012; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Rapee & Heimberg, 1997; Van Bockstaele et al., 2014). This is because when giving a speech, for example, if you only notice the audience members displaying critical expressions and ignore the smiling faces you may believe that you are giving a terrible speech and are incompetent, fueling the fears underlying social anxiety.

This thesis explores the underlying mechanisms of biased attention to threatening stimuli for individuals with high social anxiety. Key aims of the research were to test the roles of top-down attention, bottom-up attention, and selection history in attentional orienting to emotional faces, and to examine how these differ as a function of an individual's level of social anxiety. Methodologically, the studies in this thesis employed experimental paradigms administered to participants via computer, in conjunction with self-reported measures of social anxiety obtained via validated questionnaires. Social anxiety was treated as a dimensional trait in the population, consistent with current conceptualisations of the construct and methodological recommendations (Bogels et al., 2010). Of course, high levels of social anxiety symptoms indicate a risk for Social Anxiety Disorder, but importantly a diagnostic category was not necessarily invoked when the terminology "social anxiety" was employed throughout this thesis. All participants were recruited from the Australian National University undergraduate classes and the university's online advertising portals.

Thesis Structure

This thesis is comprised of nine chapters. Chapter One includes a brief introduction to the thesis. Chapter Two provides an overview of Social Anxiety Disorder. This chapter is subdivided into two main sections. The first section provides an overview of the clinical profile of Social Anxiety Disorder, including the diagnostic criteria, prevalence, course, and outcomes, and the assessment of social anxiety symptomology. The second section provides an overview of the main theoretical models of social anxiety relevant to this thesis.

Chapter Three provides an overview of visual attention. This chapter is subdivided into four sections. The first section provides a brief overview of attention. The second section explores the selective nature of visual attention. The third section describes the three main types of attention: spatial attention, feature-based attention, and object-based attention. Finally, the fourth section describes the underlying mechanisms of attention, which can be driven by top-down attention, bottom-up attention, and/or selection history.

Chapter Four reviews the research on biased attention to threat associated with social anxiety. This chapter is subdivided into four sections. Section one explores the components of attention; engagement with threat, disengagement from threat, and avoidance of threat. The measurement of attentional biases is then discussed in section two. Evidence for attention bias modification is explored in section three. Finally, in the fourth section, the relative contributions of top-down attention, bottom-up attention, and selection history are discussed in relation to the threat bias.

Chapter Five presents a study investigating the attentional mechanisms underlying the ability to orient to emotional faces. This study utilized a dot-probe design with photographs of happy, neutral, and angry faces. This is the first study, to our knowledge, that has tested the relative contributions of top-down attention, bottom-up attention, and selection history for attentional orienting to facial expressions.

Chapter Six extends on Chapter Five by investigating how these relative mechanisms of attention are affected by social anxiety. This chapter focuses in whether participants with relatively higher levels of social anxiety, compared with participants with lower levels of social anxiety, have impaired top-down control of attention in the presence of threat.

Chapter Seven investigates whether the threat bias associated with social anxiety is driven by bottom-up capture of attention or top-down attention. This study utilized a modified dot-probe task, which differentiated biases of enhanced attentional engagement with threat and delayed attentional disengagement from threat. The dot-probe task was conducted under working-memory (WM) load designed to exhaust available top-down attentional resources. This chapter, therefore, tests whether engagement and disengagement biases are present or eliminated by the addition of WM load, and are either driven by bottom-up or top-down attention.

The research in Chapter Eight was conducted due to some unusual research findings from Chapter Seven. It was hypothesized that the findings of Chapter Seven were due to methodological factors that interfered with detecting a threat bias for socially anxious participants. The new data in Chapter Eight provides a re-examination of whether the threat bias associated with social anxiety is driven by bottom-up capture of attention or top-down attention. This chapter reveals different findings to Chapter Seven, emphasising the importance of particular methodological decisions when attempting to measure the threat bias. This chapter also provides critical information on top-down contributions to the threat bias for individuals with high levels of social anxiety.

Chapter Nine presents a summary of the discoveries of this thesis and discusses how the research findings contribute to the knowledge of social anxiety based on past research as well as theoretical models. This chapter is subdivided into five main sections. Firstly, engagement and disengagement attentional biases are discussed. Secondly, the role of attentional control when orienting to emotional faces is explored. Thirdly, top-down attentional contributions to the threat bias associated with social anxiety are explored. Fourthly, this chapter considers the interactions between the race of participants and the photographic face stimuli employed and, finally, the role of top-down attention toward temporal threat biases is discussed.

Thesis Format and Publication Details

Chapters Five, Six, Seven and Eight were each prepared as individual manuscripts for journal publication. The text in these chapters is identical to the versions of the manuscripts that are published or under-review, except the numbering has been altered to reflect the page numbering of the thesis.

Currently, Chapter Seven has been published and Chapters Five, Six, and Eight are under review following requests for revisions. I am the first author of all the manuscripts and contributions from the authors listed are outlined at the start of each chapter. Note that Chapter Seven was published under my maiden name of H. L. Boal. Publication status for each manuscript is as follows:

Chapter Five:

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Chapter Six

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01/07/2019). The effect of social anxiety on top-down attentional orienting to emotional faces**.**

Chapter Seven

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Chapter Two. Literature Review: Clinical and Theoretical Overview of Social Anxiety

Chapter Overview

This chapter provides a brief clinical profile of Social Anxiety Disorder and the major theoretical explanations of the disorder. This chapter is not an exhaustive overview of social anxiety but instead provides the reader with the empirical and theoretical foundations to understand the context for the studies in this thesis. Later chapters provide more specific information on the empirical gaps in the literature and the specific research focus of this thesis.

Introduction and Clinical Profile of Social Anxiety

This section outlines the research on the symptoms of social anxiety, which shows that these symptoms vary on a continuum from fearlessness to Social Anxiety Disorder. The course, prevalence, and outcomes of Social Anxiety Disorder and its assessment are then discussed.

Social Anxiety

Humans have a strong need to be liked and valued so as to build and maintain social relationships (Tooby & Cosmides, 1996). Hunter-gatherer societies frequently faced challenges to survival, including: resisting attacks from other people and animals, foraging for food, illness, and need for warmth. In these situations, not belonging to a social group was deadly. Even in modern society, where challenges to survival are less extreme, social isolation is associated with cognitive decline (Cacioppo & Hawkley, 2009) and early mortality (Steptoe, Shankar, Demakakos, & Wardle, 2013). This indicates that it is important for us to monitor our social environment and ensure that we are liked and accepted by others to increase our chances of survival and overall health and wellbeing. Low levels of social anxiety may, therefore, have survival value through facilitating social connectedness, but as levels rise the effects become increasingly negative and at high levels become extreme and debilitating.

As early as 1870, social anxiety received recognition as distinct from other phobias (Marks, 1970, 1985) but it was not until 1980 that Social Phobia was formally identified as a mental disorder and was included in the Diagnostic and Statistical Manual of Mental Disorders (DSM-III; American Psychiatric Association, 1980). Social Phobia, also known as Social Anxiety Disorder, is characterised by an intense, persistent fear of being negatively evaluated by others. See Table 1 for the diagnostic criteria.

Table 1

Diagnostic criteria for Social Anxiety Disorder (300.23, F40.10) as outlined in the DSM-5 (American Psychiatric Association, 2013).

A. Marked fear or anxiety about one or more social situations in which the individual is exposed to possible scrutiny by others. Examples include social interactions (e.g., having a conversation, meeting unfamiliar people), being observed (e.g., eating or drinking), or performing in front of others (e.g., giving a speech).
   Note: In children, the anxiety must occur in peer settings and not just during interactions with adults.
B. The individual fears that he or she will act in a way or show anxiety symptoms that will be negatively evaluated (i.e., will be humiliating or embarrassing; will lead to rejection or offend others).
C. The social situations almost always provoke fear or anxiety.
   Note: in children, the fear or anxiety may be expressed by crying, tantrums, freezing, clinging, shrinking, or failing to speak in social situations.
D. The social situations are avoided or endured with intense fear or anxiety.
E. The fear or anxiety is out of proportion to the actual threat posed by the social situation and to the sociocultural context.
F. The fear, anxiety, or avoidance is persistent, typically lasting for six months or more.

G. The fear, anxiety, or avoidance causes clinically significant distress or impairment in social, occupational, or other important areas of functioning.

H. The fear, anxiety, or avoidance is not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication) or another medical condition.

I. The fear, anxiety, or avoidance is not better explained by the symptoms of another mental disorder, such as panic disorder, body dysmorphic disorder, or autism spectrum disorder.

J. If another medical condition (e.g., Parkinson's disease, obesity, disfigurement from burns or injury) is present, the fear, anxiety, or avoidance is clearly unrelated or is excessive.

Specify if:

Performance only: If the fear is restricted to speaking or performing in public.

Although an actual diagnosis of Social Anxiety Disorder is based on a categorical model, in which an individual either meets sufficient criteria for a diagnosis of the disorder or does not meet sufficient criteria, it is better to view social anxiety symptoms as varying on a continuum within the population (e.g., Bogels et al., 2010). McNeil (2010) presents a model of social anxiety as a continuum from "fearlessness" at one extreme, "normal fears and anxieties" in the centre of the continuum, and "Social Anxiety Disorders" at the other extreme. This recognises that it is normal for healthy individuals to display anxiety in particular social situations, such as giving speeches, dating, and interviewing for jobs. However, high levels of social anxiety impact individuals' ability to socialise, work and study, and function on a day-to-day basis. These people often avoid social interactive and performance situations or, when they do engage in them, experience extreme distress.

Prevalence, Course, and Outcomes of Social Anxiety

The lifetime prevalence rate of Social Anxiety Disorder has been estimated to range between 7% to 12% of the population (Furmark, 2002; Kessler et al., 2005), and one-year prevalence is estimated to be between 5% to 8%. This makes it the most common anxiety disorder and one of the most common psychiatric disorders (Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996; Offord et al., 1996; Wittchen, Nelson, & Lachner, 1998). Further adding to the serious and debilitating nature of social anxiety is that it is highly comorbid with other conditions, such as depression (Stein & Chavira, 1998; Stein & Kean, 2000). Social Anxiety Disorder typically onsets in early adolescence, with a median age of 13 (Kessler et al., 2005; Wittchen & Fehm, 2003), though onset can also occur in childhood (Hirshfeld-Becker et al., 2010; Ollendick & Hirshfeld-Becker, 2002). The average gender ratio (female : male) has been found to range from equality (Moutier & Stein, 1999) to slightly higher rates of social anxiety for women (3:2 ratio; Kessler et al., 2005).

The disorder can have a devastating impact on quality of life and social and occupational functioning. Compared with healthy controls, individuals with Social Anxiety Disorder were found to have greater functional difficulties, less life satisfaction, poorer self-perceived well-being, greater likelihood to fail a grade or drop out of school (Stein & Kean, 2000), increased alcohol use (Morris, Stewart, & Ham, 2005), greater unemployment, increased suicidality, reduced social support, and relationship difficulties (Davidson, Hughes, George, & Blazer, 1993; Wittchen & Beloch, 1996). As an example of relationship difficulties, in a study of individuals with Social Anxiety Disorder and matched controls, Wittchen and Beloch (1996) found that 34% of individuals with the disorder were married compared with 57% in the control group. Individuals with Social Anxiety Disorder were more likely to have never been married and more likely to have been divorced, of those who had been married. In addition to the often debilitating impact of the disorder, social anxiety is typically a chronic condition with high relapse rates. In particular, childhood Social Anxiety Disorder is difficult to treat, with research finding lower gains in treatment compared to children with other anxiety disorders. For example, Ginsburg et al. (2011) reported that, when treated with cognitive behavioural therapy (CBT), 40.6% of children with Social Anxiety Disorder achieved remission compared with 72.0% of children with other anxiety disorders. Even treatments specifically designed to treat childhood Social Anxiety Disorder have been found to result in only a 50-70% remission rate (Beidel, Turner, & Morris, 2000; Donovan, Cobham, Waters, & Occhipinti, 2015).

The picture of social anxiety in adulthood is similarly chronic. Using retrospective interviews, Chartier, Hazen, and Stein (1998) discovered that the average duration of untreated Social Anxiety Disorder is 29 years. This is worth noting as treatment among individuals with Social Anxiety Disorder is low; across nine high-income countries, the World Health Survey found that only 20.8% of individuals with the disorder sought professional help (Ormel et al., 2008).

For individuals who do seek treatment, options include psychotherapy and psychopharmacology. From a meta-analysis of treatments for social anxiety, Mayo-Wilson et al. (2014) recommended that psychotherapy should be the first-line treatment, specifically recommending the use of CBT. The study also recommended selective-serotonin reuptake inhibitors (SSRIs) as the next course of treatment for patients who refused psychotherapy. To compare CBT and psychodynamic treatment, Leichsenring et al. (2013) recruited 495 patients with Social Anxiety Disorder and randomly assigned them to manual-guided CBT, manual-guided psychodynamic treatment, or waitlist control. CBT and psychodynamic treatments included up to 25 50-minute sessions and remission and response rates were assessed. For the study, a positive response was defined as at least a 31% score reduction of social anxiety symptoms on the Liebowitz Social Anxiety Scale. Withdrawal rates for the

CBT group, psychodynamic group, and waitlist group were 24%, 28%, and 27%, respectively. Remission rates were 36%, 26%, and 9% respectively, and response rates were 60%, 52% and 15% respectively. That is, CBT and psychodynamic treatments were superior to the waitlist for remission rates and response rates, and CBT was superior to psychodynamic treatment for remission rates. Of the patients who completed treatment, remission rates were 42% and 30% and response rates were 66% and 56% for CBT and psychodynamic treatment, respectively. These results demonstrate that psychotherapy, and in particular CBT, is an effective treatment for Social Anxiety Disorder. However, the study showed that this disorder is difficult to treat with less than half of patients receiving remission after approximately 25 sessions of treatment.

Assessment of Social Anxiety

Assessment of social anxiety can include clinical interviews, structured interviews, interviewer-rated scales, self-report measures, self-monitoring tools, and physiological measures of distress (see Herbert, Rheingold, & Brandsma, 2010). In the current thesis, I utilised self-report measures because they provide rapid, quantitative data. Two social anxiety self-report measures were employed: the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) and the Liebowitz Social Anxiety Scale-Self Report (LSAS-SR; Liebowitz, 1987). The SIAS measures anxiety experienced in social interactive situations, such as: talking to people in authority, meeting people at parties, and making eye contact. This measure consists of 20 items and, for each item (e.g., “When mixing socially, I am uncomfortable”), participants are asked to make a rating from 0 (“Not at all characteristic or true of me”) to 4 (“Extremely characteristic or true of me”). This yields a score between 0 and 80. Past research found a mean of 20 in a community group. The researchers also recommended a cut-off of 34 for probable social anxiety, which represents one standard deviation above the mean of the sample. The SIAS has been found to have good reliability.

For example, with a large university and community sample, Mattick and Clarke (1998) obtained good internal consistency (Cronbach's *a* = 0.94), test-retest reliability (correlation coefficient = 0.92), discriminant validity, and construct validity. In addition, participants who received treatment for social anxiety had significant reductions in SIAS scores whereas participants who did not engage in treatment did not show significant score reductions.

The LSAS was originally developed as a clinician-administered measure of fear and anxiety experienced in 24 social situations, such as “Going to a party” and “Meeting strangers”. However, a self-report LSAS measure has also been developed (Fresco et al., 2001). Ratings are made on two 4-point Likert-type scales, with fear rated from 0 (none) to 3 (severe) and avoidance rated from 0 (never) to 3 (usually, 68%-100%). A total score can be calculated by summing scores from both the fear and avoidance scales (maximum score = 144). In addition, 13 of the questions measure performance situations (e.g., “Giving a report to a group”) and 13 of the questions measure social interactive situations (e.g., “Speaking up at a meeting”). This measure was selected as it has good psychometric properties (Baker, Heinrichs, Kim, & Hofmann, 2002; Fresco et al., 2001; Levin, Marom, Gur, Wechter, & Hermesh, 2002; Oakman, Van Ameringen, Mancini, & Farvolden, 2003; Rytwinski et al., 2009), is brief and easily administered, and provides overall and subscale social anxiety scores. The self-report LSAS has been found to have good internal consistency (Cronbach's *a* = 0.95 for patients with Social Anxiety Disorder and 0.94 for non-anxious control participants), convergent validity, and discriminant validity (Fresco et al., 2001).

Although the current thesis utilised the SIAS in Chapter Seven (which was the first study conducted), I preferred using the LSAS for studies in Chapters Five, Six, and Eight. The SIAS specifically measures fear of social interaction rather than fear of performance situations – a separate measure, the Social Phobia Scale was instead developed for this purpose. By contrast, the LSAS provides an overall measure of social anxiety, which includes both performance and interaction fears. The LSAS was, therefore, deemed a more comprehensive measure of social anxiety. In addition, the SIAS has been criticised for its reversed-scored items, which have been found to reduce the measure's validity (Rodebaugh et al., 2011). The LSAS overcomes this limitation as all the items are positively worded and easy to understand.

Theoretical Explanations of Social Anxiety

Clark and Wells (1995): A Cognitive Model of Social Phobia

Clark and Wells (1995) proposed that people with social anxiety desire to create a favourable impression of themselves to others but believe that it is unlikely that they will achieve this and that behaving in an unacceptable manner will have disastrous consequences (e.g., rejection and loss of status and worth). This situation automatically activates an "anxiety program", which consists of a series of cognitive, somatic, affective, and behavioural changes within the individual. From an evolutionary perspective, these changes can have advantages by mobilising the individual in the face of threat and danger. However, for socially anxious individuals, the response is disproportionate to the actual danger. As seen in Figure 1, when faced with a social situation, socially anxious individuals activate dysfunctional assumptions, which cause them to interpret the social situation as dangerous. Individuals then engage in self-focussed attention, noticing their behavioural, somatic, and cognitive symptoms, which reinforces their anxiety.

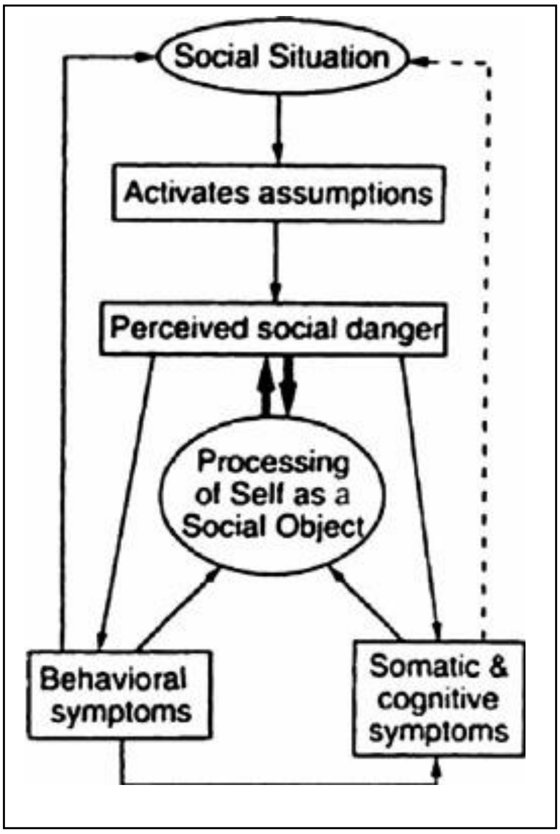

Figure 1. Clark and Well's (1995) cognitive model of social anxiety.

Clark and Well's (1995) model predicted that the following factors maintain high anxiety for individuals with social anxiety:

1. Symptoms of anxiety (e.g., racing heart and blushing) are perceived as dangerous, which further increases anxiety.
2. Increased self-focussed attention on physical sensations and anxious thoughts leading to a reduced ability to focus attention on social cues.
3. Socially anxious individuals tend to behave in ways (e.g., acting less warmly) that lead others to be less friendly toward them, thus reinforcing their anxiety.
4. Some behavioural symptoms reinforce other feared symptoms (e.g., talking rapidly increases symptoms of hyperventilation, increased heart rate, dizziness etc).

This model asserted that socially anxious individuals form impressions of themselves that they assume matches the view that others have formed. However, this impression is frequently false or exaggerated. For example, an individual who blushes when anxious may have an exaggerated image of themselves as “beetroot” red, whereby the reality is significantly less noticeable. Social anxiety is also maintained by safety behaviours. Examples of safety behaviours include: standing on the outside of a social group to avoid scrutiny, asking frequent questions in conversation to avoid talking about oneself, and drinking alcohol or taking drugs to reduce feelings of anxiety. This cognitive model also conceptualised that the following types of dysfunctional negative beliefs underpin symptoms of social anxiety:

1. Excessively high standards for social performance (e.g., “I must always be intelligent”, “I must always look my best”).
2. Conditional beliefs concerning social evaluation (e.g., “If I make a mistake, I will be disliked”).
3. Unconditional beliefs about the self (e.g., “I’m stupid”, “I’m different”, “I’m unattractive”). These beliefs are unstable, as socially anxious individuals may have a positive view of themselves when alone or with close friends and family, but have these negative self-beliefs triggered in other social situations.

Anticipatory anxiety and post-event processing were also considered in Clark and Wells’ model of social anxiety. They contended that, prior to social events, socially anxious individuals imagine themselves in the upcoming situation, predicting negative consequences and dwelling on past failures. Furthermore, after a social event, they ruminate on the event, evaluating their performance as overly negative, and often interpret it in line with past social failures.

Rapee and Heimberg (1997): A Cognitive-Behavioral Model of Anxiety in Social Phobia

Similar to Clark and Wells' (1995) model, Rapee and Heimberg (1997) proposed that individuals with social anxiety desire positive approval by others but assume that others are inherently critical. As seen in Figure 2, social anxiety symptoms are triggered by the presence of a perceived audience, which refers to any person or group of people that may observe the individual. In this model, socially anxious people develops an image of themselves based on what they imagine that the audience is perceiving. People initially have a "baseline" image of themselves from long-term memory (e.g., based on images of themselves from photos and mirrors), previous feedback from others, and past experiences in social situations. This baseline image tends to be more negative for people with Social Anxiety Disorder than people without Social Anxiety Disorder.

According to Rapee and Heimberg, individuals then engage in self-monitoring to modify their baseline image in a moment-by-moment manner, by monitoring their own facial expression, posture, actions, and physical sensations that could affect their appearance (e.g., feeling hot could result in sweating). They also monitor their audience members for feedback on their social performance (e.g., frowns or yawns). Socially anxious individuals use these sources of information to dynamically alter the mental representation that they believe others hold of them, which guides their judgement about the probability and consequences of negative evaluation. This can create a feedback loop of intensifying anxiety, with perceptions of anxious bodily sensations and others' negative evaluation leading to greater levels of anxiety, causing even greater attention to these sources of information. This model, therefore, predicted that socially anxious individuals are both hypervigilant to threat and have delayed disengagement of attention from threat.

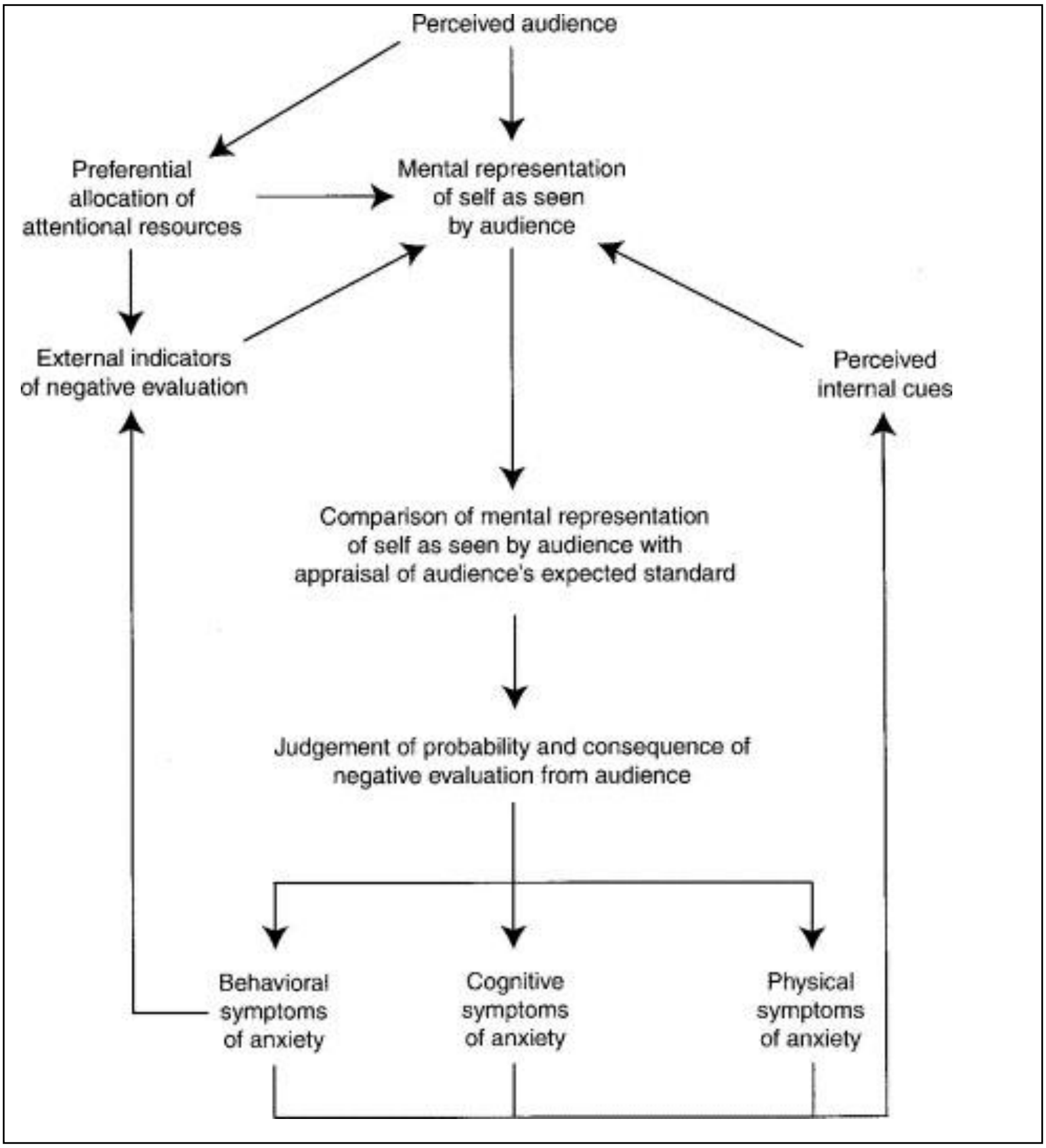

Figure 2. Rapee and Heimberg's (1997) cognitive-behavioral model of anxiety in social phobia.

In addition, Rapee and Heimberg's (1997) model predicted that socially anxious individuals experience a range of behavioural, cognitive, and physical signs of anxiety. Socially anxious individuals tend to engage in subtle avoidance behaviours (e.g., avoiding eye contact, reducing voice tone, and standing on the periphery of a group). However, this tends to result in poorer social performance, resulting in the opposite effect than intended. Socially anxious individuals also tend to have negative cognitions, believing that others are judging them. They are more likely to interpret ambiguous situations as negative, the consequences of negative social events as catastrophic, and discount positive social information. Finally, socially anxious individuals are more likely to experience physical symptoms of anxiety such as blushing, sweating, and muscle twitches. They then overestimate the noticeability of these physical signs of anxiety, leading to catastrophic predictions of resulting judgements from others, thus further reinforcing their anxiety.

Rapee and Heimberg's (1997) model has been updated by Heimberg, Brozovich, and Rapee (2010) and extended on more recently by Heimberg, Brozovich, and Rapee (2014). Though the fundamentals of the model have remained consistent, the updated model further developed the concepts of anticipatory anxiety, expected standards of performance, post-event processing and emotional regulation and expression. Thus, when anticipating a social situation, individuals with social anxiety tend to focus on the various possibilities and consequences of social failures. This is in line with research that has found that individuals with social anxiety report, both before, during, and after social events, more negatively distorted images and memories compared with individuals without social anxiety (Chiupka, Moscovitch, & Bielak, 2012; Hackmann, Surawy, & Clark, 1998).

Another core feature of the model is that socially anxious individuals believe that others have extremely high standards of them. It is highly likely that they will fall short of these standards, which the individual perceives as having "terrible" consequences. In addition to fearing negative evaluation from others, socially anxious individuals can find positive evaluation to be anxiety-producing, as it triggers fears that they cannot maintain their performance and will eventually fail. Social anxiety is, therefore, triggered when the individual observes the discrepancy between their mental representation of themselves and their perception of the audience's high standards of them (fear of negative evaluation) or they fear the consequences of drawing positive attention to themselves (fear of positive evaluation).

Furthermore, the model of Heimberg et al. (2014) emphasised the importance of post-event processing in which the individual ruminates on past social situations, analysing their own behaviour and others' reactions. In re-processing the memory, it often becomes negatively distorted, leading to increased negative affect and fearful anticipation of future social events. Finally, Heimburg and colleagues (2014) emphasised the importance of emotional dysregulation and reduced emotional expression in social anxiety. Past research has found that socially anxious individuals have reduced understanding of their emotions and are less expressive of both their positive and negative emotions (Mennin, Holaway, Fresco, Moore, & Heimberg, 2007; Mennin, McLaughlin, & Flanagan, 2009). In accordance with this, socially anxious individuals are less supportive of their partners' positive experiences (Kashdan, Ferssizidis, Farmer, Adams, & McKnight, 2013) and engage in reduced self-disclosure (Meleshko & Alden, 1993), resulting in poorer relationship outcomes. This further reinforces the belief that others will negatively evaluate them. In addition, Heimburg et al. hypothesised that socially anxious individuals engage in reduced emotional expression because they believe that showing strong emotions will result in negative social consequences (e.g. rejection and judgement). Since socially anxious individuals do not typically test out this hypothesis to either refute it or realise that the consequences of emotional expression are not catastrophic, their anxiety is maintained.

Wong and Rapee (2016): Integrated Aetiological and Maintenance (IAM) Model of Social Anxiety Disorder

The models of social anxiety discussed thus far focus predominantly on the cognitive maintaining factors of social anxiety. Recently, however, Wong and Rapee (2016) proposed the integrated aetiological and maintenance (IAM) model to provide a conceptualisation of both the developmental and maintaining factors of Social Anxiety Disorder. According to the IAM model, the threat value that individuals ascribe to social-evaluative stimuli is determined by several aetiological factors. In addition, according to the model, functioning is guided by an operating system, labelled the social-evaluative threat (SET) principle. Expressions of the SET principle vary along a continuum within the population, reflecting the level of threat value assigned to social-evaluative stimuli.

Wong and Rapee (2016) identified five aetiological factors in the IAM model, which determine the threat value assigned to social evaluative situations. Firstly, there is a genetic factor. Wong and Rapee proposed that an avoidant temperament style in some infants can lead them to avoid social-evaluative stimuli, such that they feel uncertain regarding such stimuli. In addition, having an aversion to uncertainty, such infants are more likely to judge the stimuli as highly threatening. This is in line with the finding that the temperamental factor of behavioural inhibition predicts the development of social anxiety (Chronis-Tuscano et al., 2009; Hudson, Dodd, Lyneham, & Bovopoulous, 2011; Muris, van Brakel, Arntz, & Schouten, 2011; Rapee, 2014).

Secondly, parent behaviours can teach children that social-evaluative stimuli are threatening. Examples of this include a parent telling a child that certain social-evaluative stimuli are dangerous, encouraging or allowing the child to avoid social-evaluative situations, or modelling avoidance of those situations. In addition, research has found that parenting styles that are over-controlling or over-protective, insecure parent-child attachment styles, and expressed parental anxiety in social situations predict social anxiety (Bar-Haim, Dan, Eshel, & Sagi-Schwartz, 2007; Brurnariu & Kerns, 2008; de Rosnay, Cooper, Tsigaras, & Murray, 2006; Hane, Cheah, Rubin, & Fox, 2008; Lewis-Morrarty et al., 2012). Furthermore, these parent behaviours can interact with the child’s temperament style, as avoidant or inhibited infant temperament styles tend to elicit more protective behaviour from parents (Kiff, Lengua, & Zalewski, 2011; Rubin, Coplan, & Bowker, 2009).

Thirdly, peer interactions that convey negative evaluation, such as teasing, ostracism, and bullying, can increase the threat value of social-evaluative stimuli. This is supported by research that has found that peer victimisation and low peer acceptance predicts the development of social anxiety (Levinson, Langer, & Rodebaugh, 2013; Loukas & Pasch, 2013; Ranta, Kaltiala-Heino, Frojd, & Marttunen, 2013; Siegel, La Greca, & Harrison, 2009; Tillfors, Persson, Willen, & Burk, 2012).

Fourthly, increased social-evaluative threat can be influenced by the experience of stressful or traumatic life events, such as interpersonal conflict, or physical, emotional, or sexual abuse. Wong and Rapee (2016) predicted that negative life events will have a greater impact on threat value if they are direct rather than indirect, the individual experiences multiple life events, and if they occur at particularly sensitive periods in development (e.g., early childhood).

Finally, cultural characteristics can affect the threat value of social-evaluative stimuli. For example, Wong and Rapee considered that some cultures can have specific norms, which if violated, result in negative evaluation from others. Therefore, these five aetiological factors constitute risk factors for increasing the threat value represented in the SET principle. The SET principle is then realised by particular neurobiological and cognitive effects. Specifically, according to the IAM model, heightened activation of the amygdala is associated with social-evaluative situations. In addition, the SET principle is associated with negative cognitions regarding the danger of social-evaluative situations. This includes negative beliefs about the self, social-evaluative beliefs, social-evaluative imagery, and interpretation biases. These aetiological factors are outlined in Figure 3.

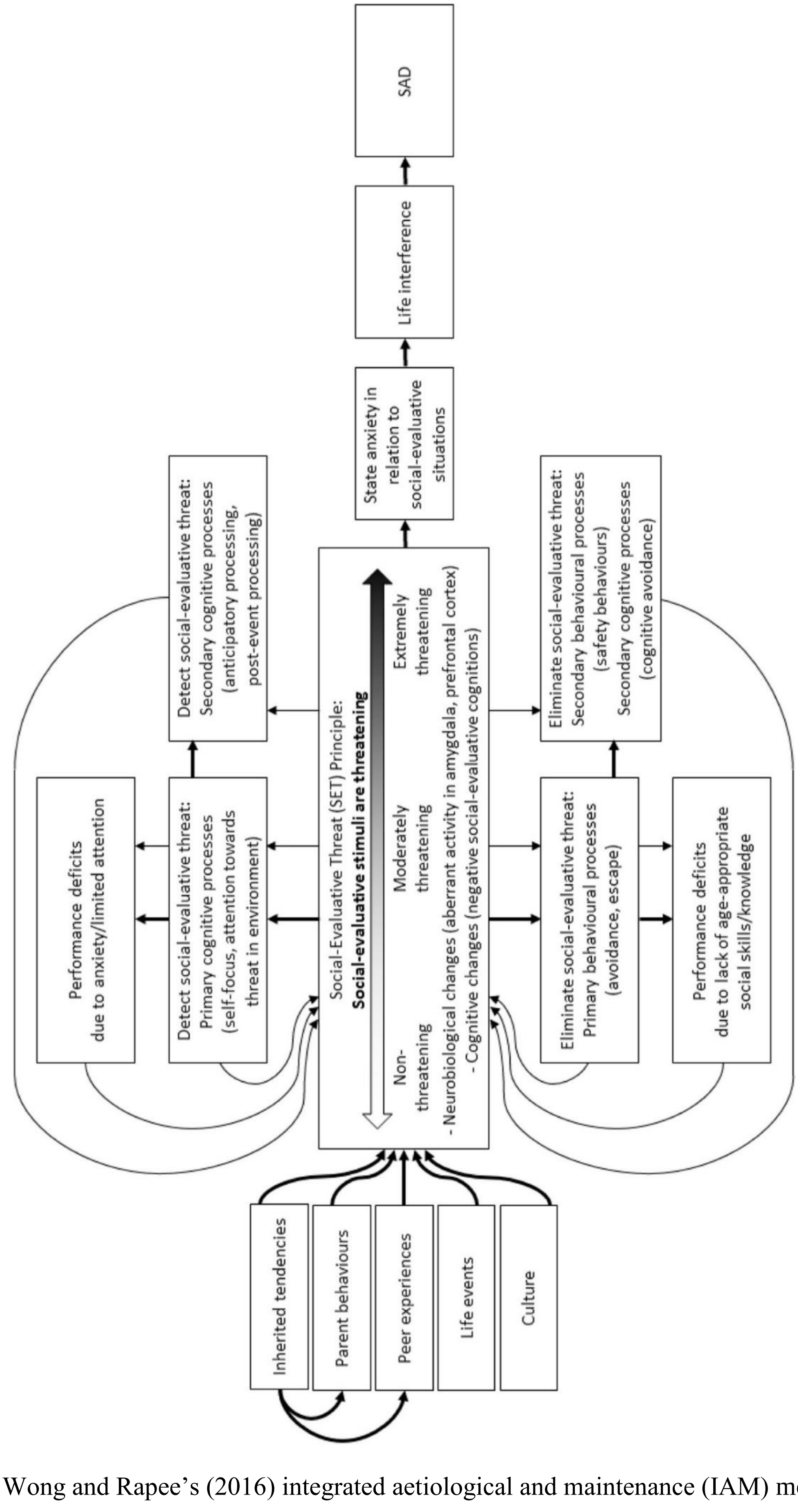

Figure 3. Wong and Rapee's (2016) integrated aetiological and maintenance (IAM) model.

As seen in Figure 3, in response to high threat value, cognitive processes emerge that increase attention to both the *self* (e.g., to monitor how one's performance or appearance may be observable to others or detect bodily signals or negative cognitions associated with social-evaluative threat) and the *external environment* (e.g., to detect signs of negative evaluation from others). In addition, behaviours are undertaken to eliminate social-evaluative threat (e.g., avoidance or escape of the situation). These cognitive and behavioural processes can lead to performance deficits in social-evaluative situations through anxiety or reduced availability of attentional resources to direct to the situation. In addition, avoidance of social situations leads to reduced opportunities to develop age-appropriate social skills and knowledge.

Wong and Rapee proposed that these primary cognitive processes lead to secondary cognitive processes; namely anticipatory processing and post-event processing. This increases the detection of social stimuli that are interpreted as threatening, thus reinforcing the high threat value of social-evaluative stimuli. In parallel, secondary attempts to eliminate social threat emerge, which include behavioural avoidance (e.g., safety behaviours) and cognitive processes (e.g., cognitive avoidance). These processes prevent the individual from engaging effectively in social-evaluative situations, tending to lead to actual negative evaluation from others and so increasing the threat value associated with the SET principle. Due to a high threat value placed on social-evaluative situations, the individual is then likely to experience high state anxiety when faced with these situations, thus increasing the likelihood of life interference and Social Anxiety Disorder onset. Although some components of the IAM model require further empirical validation (e.g., the influences of culture and negative life events), this model provides a generally empirically supported and comprehensive picture of the development and maintenance of social anxiety.

Summary and Links to the Present Thesis

In addition to providing an overview of social anxiety and its measurement, this chapter outlined the three major models of social anxiety relevant to this thesis: Clark and Wells' (1995) cognitive model of social phobia, Rapee and Heimberg's (1997) cognitive-behavioral model of anxiety in social phobia, and Wong and Rapee's (2016) IAM model of Social Anxiety Disorder. These models provided the groundwork for the research in this thesis, as they emphasised the importance of cognitive factors in maintaining social anxiety, as well as potentially playing a causal role, and proposed that biased allocation of attention to threat is a major contributing factor to symptoms of social anxiety.

Interestingly, Clarke and Wells (1995) proposed that this effect occurs through self-focussed attention to physical sensations and anxious thoughts. Although there has been considerable support for the role of self-focussed attention in socially anxiety (e.g., Gaydukevych & Kocovski, 2012; Glick & Orsillo, 2011; Hodson, McManus, Clark, & Doll, 2008), Clark and Wells' (1995) model overlooked the role of biased *visual* attention to threat. However, this factor is important. In line with Rapee and Heimberg's (1997) and Wong and Rapee's (2016) predictions, studies indicate that social anxiety is associated with biased visual attention to threatening words, facial expressions, and body language (e.g., Amir, Elias, Klumpp, & Przeworski, 2003; Grafton & MacLeod, 2016; Lin, Hofmann, Qian, Kind, & Yu, 2016; Pishyar, Harris, & Menzies, 2004). However, Rapee and Heimberg and Wong and Rapee's models have limitations in that they do not provide more specific predictions regarding when enhanced attention and delayed disengagement with threat may occur or the role of attentional avoidance from threat. The current thesis aimed to deepen our understanding of the mechanisms that result in biased attention to threat.

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Chapter Three. Visual Attention

Chapter Overview

This chapter provides an overview of visual attention, discussing how visual attention is a selective process that enhances the processing of some visual information at the expense of other information. This chapter then explores different types of attention as well as the relative roles of top-down attention, bottom-up attention, and selection history in orienting to features in our visual environment. As visual attention has been extensively researched for many decades, this chapter is not intended to provide a complete discussion of the field. This chapter, therefore, focuses on overviewing visual attention to provide the core knowledge required to understand the visual attention mechanisms relevant to this thesis. Note that a discussion of temporal attention, which is a form of visual attention, is included in Chapter Nine when considering directions for further research.

Overview of Attention

Despite the maxim by William James that "Everyone knows what attention is" (James, 1890, *p*. 381), there has been ongoing confusion and debate regarding its definition. A recent taxonomy by Chun, Golomb, and Turk-Browne (2011) proposed that the function of attention is to select, modulate, and sustain focus on information to guide behavior. Attention is, therefore, needed to select relevant information and ignore irrelevant information. A broad distinction in the attention literature has been made between external and internal attention (Chun et al., 2011). More specifically, external attention, also known as perceptual attention, refers to the selection and modulation of sensory information (e.g., from vision, hearing, touch, smell, and taste). By contrast, internal attention refers to the selection and modulation of internal sources of information, such as working memory, long-term memory, task sets, and response selection (see Chun et al., 2011, for a discussion). However, biases in visual attention, which falls within the category of external attention, is theorised to be particularly relevant to social anxiety and is explored in detail in this chapter.

Attention as a Selective Process

Attention is a limited-resource system in which visual stimuli compete for cortical representation (Broadbent, 1958; Neisser, 1967; Treisman, 1960). During waking life, we are bombarded with visual information, yet there is a finite amount of capacity available in the brain, which places restrictions on any person's ability to process visual information (Clarke & Sokoloff, 1994; Lennie, 2003). Since we cannot process all available information, a selection process is necessary to determine what information is to be prioritised for further processing, versus delaying or ignoring information. According to the biased-competition theory, when multiple stimuli appear in the visual field, the stimuli are not processed independently but instead they activate populations of neurons that interact in a competitive manner. Specifically, both single-cell and neuroimaging studies have found that when multiple stimuli are presented in the same receptive field, they are processed in a mutually suppressive manner (see Desimone & Duncan, 1995). Research has compared neural responses in the monkey brain when one stimulus is presented compared with two simultaneously presented stimuli, finding that simultaneous presentations resulted in neural responses that were a weighted average of the response to one stimulus (Reynolds, Chelazzi, & Desimone, 1999).

To understand how we prioritise some visual information above other information, a "spotlight" has been employed as a metaphor of visual selection, suggesting that attention is shifted from object to object resulting in enhanced processing within a selected location in space (Posner, 1980). This model facilitates our understanding of the limited capacity nature of selective attention. Only a small amount of visual information can receive high-level processing at any one time and this relevant information is selected in our visual field so as to best guide our behaviour. Yet, although this spotlight metaphor helps to understand how we attend to specific stimuli (e.g., when reading a book), it does not describe the ability to attend to multiple stimuli in a visual field at once (e.g., when monitoring both the ball and other players during a game of soccer). To account for these types of flexible attentional strategies, the attentional zoom-lens model was developed. This model posited that the size of the attentional focus can be varied continuously (Eriksen & St. James, 1986; LaBerge & Brown, 1989; Müller, Bartelt, Donner, Villringer, & Brandt, 2003). Processing is still selective and capacity-limited, however, a trade-off between the size of the attended area and resolution of processing occurs. Thus, attention can either be focussed on a small visual location, leading to detailed focussed processing, or spread more broadly throughout a visual field with a corresponding loss of spatial resolution and processing efficiency (Castiello & Umiltá, 1992; Castiello & Umiltà, 1990; Eriksen & St. James, 1986). However, there are limitations to the spotlight and zoom-lens metaphors. For instance, they do not explain the fact that humans can allocate attention to non-contiguous areas (e.g., an annulus, see Jefferies & Di Lollo, 2015), and the fact that attention appears to have a gradual gradient rather than a hard edge (White, Ratcliff, & Starns, 2011). Although the spotlight and zoom-lens metaphors are helpful to understand space-based attention, attention can also be deployed to features and objects in the visual field. These separate types of attention are discussed more in the next section.

Types of Attention

Three main types of visual attention have been identified: (1) spatial attention, in which attention is shifted to a particular location in space, either overtly, with accompanying eye movements, or covertly, without accompanying eye movements; (2) feature-based attention in which overt or covert attentional orienting occurs based on stimulus features (e.g., colour, motion, or orientation) regardless of the location of the stimulus; and (3) object-based attention in which overt or covert attentional orienting is deployed by object structure (Carrasco, 2011).

An early demonstration of spatial attentional orienting comes from Posner's cueing paradigm (Posner, 1980; Posner & Cohen, 1984) in which a target was presented in one of two locations and participants responded to whether the target was present or not. An initial cue (e.g., an arrow) was presented to indicate the probable location of the target. Typically, faster reaction times (RTs) have been found in the cued, relative to the opposite (uncued) location, suggesting that attention was oriented toward that location (Posner, 1980; Posner & Cohen, 1984). Space-based attention, therefore, reflects our ability to move attention, like a beam of light, across our visual field; enhancing processing in the location that attention falls upon (e.g., when scanning the names of books on a library shelf or looking through clothes on a rack).

Although vision research has largely focussed on the effects of shifting attention between particular locations in the visual field, attention can also be guided by particular visual features, such as orientation, colour, or direction of motion (Boynton, 2009; Haenny, Maunsell, & Schiller, 1988; Martinez-Trujillo & Treue, 2004; Maunsell & Treue, 2006; Treue & Trujillo, 1999). In cluttered scenes, feature-based attention can be used to orient quickly to objects when its feature is known but not its location. For example, when searching for a friend in a crowd, knowing that they are wearing red allows for selective attention toward red objects. Research has found that feature-based attention can select features within a particular dimension (e.g., red or blue objects, upward or downward motion, and vertical or horizontal orientation; Baldassi & Verghese, 2005; Haenny et al., 1988; Lankheet & Verstraten, 1995; Ling, Liu, & Carrasco, 2009; Liu, Larsson, & Carrasco, 2007; Liu, Stevens, & Carrasco, 2007; Martinez-Trujillo & Treue, 2004; Muller et al., 2006; Saenz, Buracas, & Boynton, 2003), as well as orient to particular dimensions of features (e.g., motion or orientation; Chawla, Rees, & Friston, 1999; Liu, Slotnick, Serences, & Yantis, 2003). In addition, feature-based attention is not constrained to the location of stimuli that is being attended but is, instead, spread throughout space (e.g., Boynton, Ciaramitaro, & Arman, 2006; Felisberti & Zanker, 2005; Hayden & Gallant, 2005; Liu & Mance, 2011; McAdams & Maunsell, 2000; Saenz, Buracas, & Boynton, 2002, 2003). For example, McAdams and Maunsell (2000) measured neuronal responses in the V4 area of the cortex of monkeys whilst they performed a visual task. The responses of most V4 neurons were affected by whether the monkeys were attending to the orientation or colour of a stimulus, even when the stimulus fell outside of the neuron's receptive field. These results demonstrate that attentional selection is not only based on spatial location, but also involves searching for a particular feature triggering changed neural activity throughout the visual field.

Finally, rather than shifting attention to spatial locations or features, a third category of attention has been recognised; object-based attention. In this type of attentional selection process, all parts of an object may be selected and processed concurrently. This allows us, for example, to easily attend to a dog at a dog-park, even though it may run behind other dogs and rapidly change direction. Object-based attention was demonstrated by Egly, Driver, and Rafal (1994) in a cueing paradigm. In this experiment, cueing one end of a rectangle resulted in improved performance at the other end of the rectangle compared with performance to a target at an equally distant location that was in a separate rectangle. Further evidence is that individuals can engage in tracking multiple moving objects across a scene (Sears & Pylyshyn, 2000), and can attend to one of two objects even though they share the same location (Blaser, Pylyshyn, & Holcombe, 2000).

Although attention to space, features, and objects have been differentiated in the literature, evidence indicates that attentional selection can result from interactions between them (Kravitz & Behrmann, 2011; Leonard, Balestreri, & Luck, 2015). For example, Leonard et al. (2015) found that the impact of distractors on feature-based attentional capture effects increased when the distractors where closer to the location of focussed spatial attention. This indicates that feature-based attention is modulated by spatial attention. A further difficulty of these categories is differentiating features and objects from one another. That is, attention can be deployed to both *parts* of objects (Vecera, Behrmann, & Filapek, 2001) as well as *global representations* of objects (Yeari & Goldsmith, 2011). So, for example, when looking at a nose on a face, should that be considered a feature or an object in its own right? Thus, in real-world visual processing, space-, feature-, and object-based attention may flexibly interact, resulting in enhanced processing of particular objects or features and provide scene-wide representations of our visual world.

Attentional Selection by Top-Down, Bottom-Up, and Selection History Mechanisms

The selection of visual stimuli by attention can be driven by three mechanisms: top-down attention, bottom-up attention, and selection history. More specifically, when navigating our visual world, we may use volitional, top-down attention to search for our keys, a friend in a crowd, or a particular piece of fruit in a supermarket. However, we may also attend to objects that we did not intend to look for. That is, stimulus-driven, bottom-up attention allows us to orient to objects such as a swooping bird, the flashing lights of a fire truck, or an unexpected ball thrown at us (see Corbetta & Shulman, 2002). More recently, a third mechanism of attention has also been recognised: selection history (Awh, Belopolsky, & Theeuwes, 2012). Selection history refers to the capture of attention by a visual stimulus due to past selection or past reward history, even if it no longer matches the individual’s top-down goals. For example, after finding your keys using top-down attention, another irrelevant key may capture your attention even though you were no longer searching for it. Each of these mechanisms of attention will be discussed in more detail below.

Bottom-Up Attention

A common conceptualisation of attentional selection is that preferential attention is directed toward the most salient visual stimuli, locations, or visual features that evoke the strongest neural response within the visual field (Desimone & Duncan, 1995; Koch & Ullman, 1985). It has been theorised that an early topographical map of the visual environment is encoded in a bottom-up manner based on features such as colour, motion, and orientation. This is fed to a “saliency map”, that prioritises the most conspicuous or interesting stimuli in the visual scene. Attention is then oriented to the spot on the map with the highest saliency (Koch & Ullman, 1985).

The neural basis of bottom-up attention is initiated from the primary visual cortex (V1), ascending into multiple visual areas and then separating into the ventral pathway focussed on object- and feature-based attentional processing, and a dorsal pathway focussed on movement- and space-based processing (Ungerleider & Haxby, 1994; Ungerleider & Mishkin, 1982). Components of the ventral pathway include V1, V2, V3, V4, and the inferior temporal (IT) cortex that then projects to the ventral part of the lateral prefrontal cortex (PFC). Components of the dorsal pathway are V1, V2, V3, middle temporal (MT) area, and medial superior temporal (MST) area and areas within the posterior parietal cortex (PPC), which project to the dorsolateral part of the PFC (dlPFC) (see Katsuki & Constantinidis, 2014). Processing along these pathways is hierarchal, with each stage building upon the previous stage to form more complex representations of the visual field.

Top-Down Attention

In addition to bottom-up attentional capture based on stimulus salience, it has long been recognised that attentional orienting can also depend on current goals (Wolfe, 1994). That is, visual processing is not solely determined by feedforward processing from lower to higher visual cortical areas. Instead, neural tuning can be impacted by feedback mechanisms from higher areas of the cortex (Lamme & Roelfsema, 2000). For example, neurons in V1 can change their tuning for orientation (Ringach, Hawken, & Shapley, 1997) and colour (Cottaris & De Valois, 1998) over the course of their responses. This research provides initial evidence that top-down attentional processing influences attentional selection by feedback mechanisms.

It has been proposed that the attentional system includes a “priority map”, which integrates input from bottom-up and top-down factors (Bisley & Goldberg, 2010; Serences & Yantis, 2006). Indeed, facilitated behavioural and neuronal responses have been found based on top-down cues to particular spatial locations and stimulus features (e.g., colour) (Corbetta, Miezin, Dobmeyer, Shulman, & Petersen, 1990; Heinze et al., 1994; Hillyard & Munte, 1984; Kingstone, 1992; Posner, 1980; Vanvoorhis & Hillyard, 1977; Woldorff et al., 1997). More specifically, top-down attention results in enhanced neural activity for the target location, feature, or object, while neural activity for irrelevant stimuli is supressed. This process has been associated with areas within the dorsal and ventral pathways, including V1, V2, V4, IT, MT, the PPC, and the PFC (Noudoost, Chang, Steinmetz, & Moore, 2010). However, the origin of top-down attentional signals has been linked to the PFC and PPC (see Katsuki & Constantinidis, 2014). For example, microstimulation of the frontal eye field (FEF), located in the PFC, has been found to result in an enhanced firing rate in visual areas and improved performance on visual attention tasks (Moore & Armstrong, 2003; Moore & Fallah, 2001, 2004). Conversely, inactivation of the FEF using microinjections of muscimol, which causes suppression of neurophysiological activity, resulted in performance deficits on visual attention tasks (Wardak, Ibos, Duhamel, & Olivier, 2006). It is, therefore, thought that top-down attentional selection is driven by feedback projections from the PFC and PPC to the visual cortex (see Figure 4). Consistent with this, Ninomiya, Sawamura, Inoue, and Takada (2012) found that segregated pathways link areas of the PFC and PPC to specific areas within the dorsal and ventral streams. Research investigating the neural systems associated with top-down and bottom-up attention indicates that overlapping brain areas are involved in both attentional systems (e.g., the PFC and PPC). However, despite this overlap in neural activity, research has found that top-down and bottom-up attention have distinct processes, which provide a priority map for the selection of visual stimuli (Katsuki & Constantinidis, 2014).

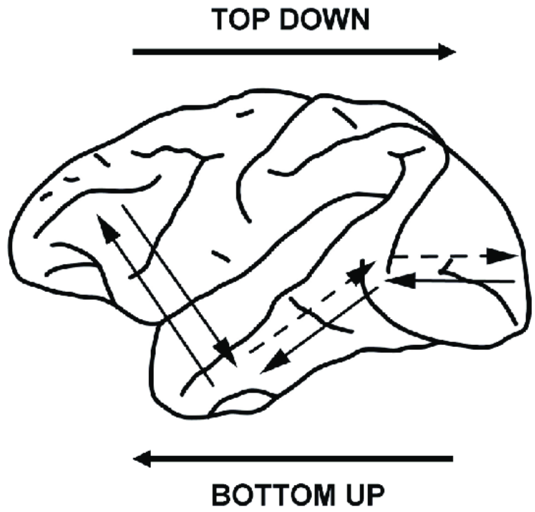

Figure 4. Top-down and bottom-up attentional processing in the human brain (Sinke, Neufeld, Zedler, & Emrich, 2014).

Feature-based top-down control of attention has been demonstrated in the research of contingent capture theory. According to contingent capture theory, bottom-up visual cues will only capture spatial attention if they match the top-down attentional set of the participant. In a study demonstrating this, Folk, Remington, and Johnston (1992) presented participants with a visual task in which they reported the presence of an “X” or “+” in an array. On each trial, the target was defined by its onset (the appearance of a single target) or its colour (red amongst white distractors). On some trials, a cue (four dots surrounding a placeholder) preceded the target and was also defined by onset or colour. Folk et al. (1992) found that valid cues, which signalled the correct location of the to-be-presented target, resulted in faster responding to the target, and invalid cues, which signalled an incorrect location, resulted in slowed responding. This well-studied phenomenon is typically known as a cueing effect. However, cueing *only* occurred if the cue matched the properties of the target. Therefore, when the target was defined by onset, onset cues affected performance, and when the target was defined by colour, colour cues affected performance. By contrast, when the properties of the cue did not match the target, participants' attention was not captured by the cue. This indicates that salient stimuli do not always capture attention. Instead, attentional orienting is dependent on top-down control settings. This finding has been confirmed by decades of research on contingent capture (for a review, see Folk & Remington, 2010).

Further research examining the distinction between bottom-up and top-down attention demonstrated that target stimuli will "pop-out" of a visual display in a bottom-up manner if they differ substantially from distractors (e.g., a red stimulus amongst green distractors) (Duncan & Humphreys, 1989; Treisman, 1985; Treisman & Gelade, 1980; Wolfe, 1994). However, if the target stimulus does not differ substantially from distractors, it can be identified using top-down attention by searching each stimulus within the visual field, one-by-one (Wolfe & Horowitz, 2004). This research indicates that bottom-up attentional capture should be invariant to task demands, whereas top-down attention is affected by task demands (e.g., the number of stimuli in an array).

In addition to pop-out effects, a further distinction between top-down and bottom-up attention is the involvement of working-memory (WM) resources. WM is a limited-capacity system and is responsible for the active maintenance of information, particularly the storage and rehearsal of information and executive functions (Conway et al., 2005). Indeed, WM can be thought of as synonymous with cognitive control (i.e., top-down attention) (Qi et al., 2014). Since bottom-up attention places few demands on WM resources, it is relatively unaffected by WM load (Jonides, 1981). By contrast, top-down attention requires WM resources (de Fockert, Rees, Frith, & Lavie, 2001; Downing, 2000). Therefore, if a high WM load (e.g., remembering a digit string or solving an arithmetic task) is added to a visual attentional task, participants will have limited top-down resources available to perform the visual attentional task. Hence, if performance is unaffected by the WM load, it can be concluded that this task is driven by bottom-up attention. By contrast, if performance is impaired by the addition of high WM load, this reveals that top-down attention is required to perform the task (see Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). That is, top-down attention is characterised by the goals of the individual and requires WM resources, whereas bottom-up attention occurs relatively automatically and depends on stimuli salience.

Selection History

The theory of a dichotomy between top-down attention and bottom-up attention, while long-standing in cognitive psychology, has been criticised for not accounting for selection history (Awh et al., 2012). Selection history recognises that visual attentional capture can occur based on an individual's past selection and reward history (Awh et al., 2012). In an early demonstration of selection history, Maljkovic and Nakayama (1994) conducted a pop-out visual search experiment in which participants showed speeded responses to a target defined by colour or spatial frequency cues. Faster RTs were found when the same target repeated across two trials, compared with when it switched. In fact, this speeding of responses occurred even when participants knew with 100% certainty the identity of the target on the upcoming trial, indicating that selection history can guide attention even when it differs from one's current goal (Belopolsky & Awh, 2016; Theeuwes, Reimann, & Mortier, 2006; Theeuwes & Van der Burg, 2013).Extending on this work, Theeuwes (2013) argued that the contingent capture effects found in past research can be explained entirely by selection history (referred to by Theeuwes as "bottom-up priming"). This is because, previously, contingent capture paradigm experiments employed blocked designs in which participants were asked to search for the same stimulus feature throughout an entire block of trials. Thus top-down attention was confounded with selection history effects. In particular, in Experiment 2 of their article, Theeuwes et al. (2006) demonstrated that controlling for selection history as a factor can eliminate the pattern of results that would typically be interpreted as top-down effects. In this experiment, participants searched for a singleton (diamond or red circle) after seeing a cue. This cue could indicate the probable identity of the singleton (“shape” or “colour”) or was a neutral cue that did not predict the target’s identity (“equal”). The predictive cue trials and neutral trials were blocked. In addition, to prevent response priming, participants did not respond to the singleton itself, but instead reported the orientation of a line that was presented inside the singleton. In this study, no cueing effects were found, as foreknowledge about the singleton’s identity did not facilitate performance. Theeuwes et al. (2006) concluded that top-down feature cues cannot be used to guide attention to a target and, instead, cueing effects are driven by selection history.

However, contrary to the assertions made by Theeuwes (2013) and Theeuwes et al. (2006), other research indicates that goal-driven, top-down attention can be used to guide selective attention (Belopolsky & Awh, 2016; Chen & Cave, 2015). For instance, Belopolsky and Awh (2016) hypothesised that participants will not employ top-down attentional guidance for pop-out arrays because search can be easily guided by bottom-up attention. However, in more difficult arrays when stimulus features do not pop-out, top-down, feature-based guidance of attention will be employed. Indeed, that is what these researchers found. Belopolsky and Awh (2016) employed two conditions, one in which the target circle was a unique colour to the distractor (pop-out condition) and one in which the target circle and distractors were all presented in different colours (heterogeneous condition). When the pop-out trials were blocked, there was no effect of cueing. By contrast, in the heterogeneous condition, and in a second experiment in which heterogeneous and pop-out trials were intermixed in a condition, cueing was found. This indicates that top-down, feature-based attention can be used to guide early attention, but it is only employed when it is helpful to the task. Furthermore, although it is likely that different attentional mechanisms interact to guide attention (Bisley & Goldberg, 2010; Serences & Yantis, 2006), top-down attention, bottom-up attention, and selection history have separate and distinguishable contributions to visual attention.

Summary and Links to the Present Thesis

This chapter provided an overview of basic visual attention, outlining that attention is a selective process and can be guided to spatial locations, features, and objects. Furthermore, attentional guidance can be driven by top-down attention, bottom-up attention, and selection history. Although there is a body of research exploring the relative roles of top-down attention, bottom-up attention, and selection history toward basic stimuli, such as shapes and colours, the roles of all three of these attentional processes have not been systematically explored in relation to either emotional faces or social anxiety. This is surprising, given that this framework is core to cognitive psychologists' understanding of how attentional orienting works, and the fact that there is broad interest in attention to emotional faces. This theoretical framework has significantly elucidated our understanding of attentional orienting to basic features and, therefore, it holds much promise in improving our understanding of attentional orienting to complex properties such as threat. Furthermore, the bias to threatening facial expressions associated with social anxiety has considerable clinical significance, yet it has not always enjoyed the same strong theoretical basis as visual-attention research in cognitive psychology. The research in this thesis rectifies this via applying this fundamental framework to elucidate our understanding of the mechanisms underlying biased attention to threat in social anxiety. The next chapter discusses how the threat bias and these attentional processes can be tested to further understand social anxiety symptomatology.

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Chapter Four. Attentional Biases Associated with Social Anxiety

Chapter Overview

Theoretical models indicate that a critical maintaining factor for social anxiety is selective attention to threat, such as socially threatening words (e.g., “stupid”, “ugly”) or faces (e.g., those displaying expressions of anger, disgust, or contempt) (Rapee & Heimberg, 1997; Wong & Rapee, 2016). The current thesis focussed specifically on visual attention to faces as, arguably, faces are more ecologically valid than words as they represent the main threats faced in daily social interactions (Heinrichs & Hofmann, 2001). A body of research has emerged attempting to determine the exact nature of this bias and how it can be best measured. In this chapter, the components of the attentional bias are discussed, examining the research findings for biases in first the initial engagement with threat, then delayed disengagement from threat, and finally avoidance of threat. This chapter then outlines the primary techniques for measuring this bias. An overview of attention bias modification is then provided. Finally, the contributions of top-down attention, bottom-up attention, and selection history to the threat bias are explored.

Components of Attentional Biases

Unsurprisingly, due to the multifaceted nature of attention, a large body of literature has developed with differing methods for how to both conceptualise and measure attentional biases. Within visual attention, Posner and Petersen (1990; see Petersen and Posner, 2012 for an updated model) proposed that three relatively separate attentional networks are responsible for alerting, orienting, and executive control. More specifically, the alerting network is responsible for maintaining vigilance during a task. For example, a warning signal prior to the onset of a target can result in faster target detection, even though the warning did not provide additional information about the target (e.g., location). The orienting network is responsible for selecting the modality or target location, and the executive is responsible for target detection and conflict resolution. The Attention Network Task has been developed to measure these three networks (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Threat-related biases in visual attention have largely focused on the orienting network of visual attention specifically. Within the orienting function, attention to threat may be comprised of facilitated attention to threat, delayed disengagement from threat, and/or attentional avoidance of threat (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Koster, Verschuere, Crombez, & Van Damme, 2005; Mogg, Bradley, Miles, & Dixon, 2004; for a review, see Cisler & Koster, 2010). Facilitated attention to threat refers to the enhanced likelihood or speed of orienting attention toward a threatening stimulus. Difficulty disengaging from threat refers to the speed or ease of shifting attention away from a threatening stimulus toward another stimulus. Finally, avoidance of threat refers to the situation in which attention is preferentially allocated to the location opposite to the location of the threatening stimulus.

According to the vigilance-avoidance hypothesis (Mogg, Bradley et al., 2004), anxious individuals demonstrate initial vigilance for threat, followed by avoidance of threat. This suggests a temporal relationship between the components of facilitated attention and avoidance. Though not included in the vigilance-avoidance hypothesis, a third potential mechanism of the threat bias is delayed disengagement from threat. The recognition that there are several separate components of the attention process demonstrates the importance of separately measuring them and considering the time course of facilitated attention to threat, delayed disengagement from threat, and avoidance. Below, I review the evidence for biases toward threat for individuals with high social anxiety.

Measurement of Attentional Biases

The Stroop Task

Initial studies assessing the threat bias utilised the Stroop task. In a typical Stroop task, participants are asked to respond to the colour of a projected word, where the meaning of the word is irrelevant. Faster RTs are typically found when the word colour and meaning match (e.g., when the word “YELLOW” is written in yellow) compared with when they are incongruent (e.g., “YELLOW” is written in blue). This paradigm reveals participants’ failure to ignore the word meaning. An emotional Stroop paradigm is a modified form of the classical Stroop test and is designed to measure attentional biases to emotional stimuli, such as threatening words. Research has found that socially anxious individuals demonstrate slower RTs for colour-naming of socially threatening words (Becker, Rinck, Margraf, & Roth, 2001; Hope, Rapee, Heimberg, & Dombeck, 1990; Maidenberg, Chen, Craske, Bohn, & Brystritsky, 1996; Mattia, Heimberg, & Hope, 1993). It was initially concluded that these slowed RTs reflect enhanced allocation of attention to threatening words for socially anxious individuals. However, other possibilities are that socially anxious individuals process both the neutral and threatening words equally but the presence of threat words results in a more negative affective state which slows RT (MacLeod, Mathews, & Tata, 1986), or, that socially anxious individuals actually display emotional avoidance of the threatening words and the slower RTs are due to increased effort or time needed in the stage of initially avoiding processing the threatening words (de Ruiter & Brosschot, 1994). Furthermore, the Stroop task tests participants’ attention to a threatening stimulus at a centrally-located position. Since participants are instructed to orient to this location throughout the trial, the Stroop task cannot assess the separate components of attention of facilitated engagement, delayed disengagement, and avoidance of threat. These limitations are addressed by the visual search task and the dot-probe task which, by contrast, measures participants’ ability to orient their attention through space.

The Visual Search Task

In the visual search task (Öhman, Flykt, & Esteves, 2001; Rinck, Becker, Kellermann, & Roth, 2003), participants are directed to search for a target stimulus that is embedded in a matrix of distracting stimuli (e.g., an angry face amongst neutral faces), and make some type of prescribed response regarding the target (e.g., detect the presence or absence of the target on each trial). Increased engagement with threat is defined as faster RTs to a threatening target stimulus appearing amongst neutral stimuli compared with a neutral target stimulus amongst neutral distractors. By comparison, a disengagement bias is reflected by slower RTs to a neutral target stimulus presented amongst threatening distractors compared with a neutral target stimulus amongst neutral distractors. In a visual search task, also known as a “face-in-the-crowd” paradigm, Gilboa-Schechtman, Foa, and Amir (1999) presented participants with 12 photographs of faces. On each trial, these photographs either consisted of all the same emotional expression (happy, angry, neutral, or disgusted), or one photograph depicted a different expression to the other 11 photographs. Participants responded to whether there was an odd-one-out or not on each trial. Gilboa-Schechtman et al. (1999) found that all participants had faster RTs to the angry face compared with the happy face amongst neutral distractors. This difference in RT was larger for socially anxious individuals than for non-anxious controls, which they concluded reflects a threat bias. However, inconsistent results have been found. For instance, Juth, Lundqvist, Karlsson, and Öhman (2005) reported the opposite finding that happy faces were detected more rapidly than angry faces, and that social anxiety was not associated with different RTs. Further research has also found that, with a non-clinical sample, faster detection of happy or angry face advantages was dependent on the type of face database employed (Savage, Lipp, Craig, Becker, & Horstmann, 2013). This indicates that the results of visual search tasks are easily influenced by low-level perceptual differences across faces in different databases. In addition to inconsistent results, the visual search task approach has been criticised for possibly confounding early attentional processes with later processes, such as the judgement and interpretation of stimuli (Staugaard, 2010). Another potential deficiency for some of the visual search research is that it has not sufficiently considered the role of the distractor context (Frischen, Eastwood, & Smilek, 2008). For example, it is difficult to draw conclusions about performance across conditions with differing distractor backgrounds (e.g., searching for an angry face amongst happy distractors versus a happy face amongst angry distractors), as results could reflect enhanced attentional orienting to the target stimulus or differential dwell time or rejection of the distractor stimuli.

The Dot-Probe Task

In the dot-probe task (MacLeod et al., 1986), participants are simultaneously presented with two visual stimuli (e.g., two words or images) either on the top and bottom or left and right of the computer screen. In the first development of the task (MacLeod et al., 1986), participants were asked to read the top word aloud. The two words were presented for 500ms and then a probe ("*") was presented in the locus of one of the words and participants were asked to respond to the presentation of the probe as quickly as possible. More recent dot-probe paradigms (Koster, Crombez, Verschuere, & De Houwer, 2004; Mogg & Bradley, 1999; Mogg, Bradley, de Bono, & Painter, 1997; Salemink, van den Hout, & Kindt, 2007) have typically included a central fixation cross, before two stimuli (e.g., one threatening and one neutral) are presented and a probe replaces one of the images. Participants are usually asked to respond to the presence or identity of the probe. Faster RTs to the probe presented in the locus of a threatening word or image compared with a neutral word or image indicate a threat bias and are believed to reflect greater engagement of attention to the threatening image. Research has typically found that social anxiety is associated with enhanced attention to angry faces relative to neutral and happy faces (Mogg, Philippot, & Bradley, 2004; Pishyar, Harris, & Menzies, 2004). However, the dot-probe task has also found some inconsistent results. For example, when faces were paired with household objects, socially anxious participants had a bias away from faces, regardless of the emotion (Chen, Ehlers, Clark, & Mansell, 2002) and when long presentation times for faces were used (1000ms), no evidence of a threat bias was found (Gotlib et al., 2004). Also, no biases toward threatening faces for socially anxious individuals were found by Bradley et al. (1997) and Pineles and Mineka (2005).

One potential reason for the inconsistent results is that the dot-probe task does not differentiate enhanced engagement with threat and difficulty disengaging from threat. Koster et al. (2004) attempted to separately measure these two biases with a modified dot-probe task. Trials consisted of either threat-neutral or neutral-neutral stimuli. Enhanced engagement with threat was reflected by faster RTs to the probe following the threatening image compared with RTs to the probe on neutral-neutral trials. By comparison, difficulty disengaging from threat was reflected by slower RTs to the neutral image on neutral-threat trials compared with RTs on neutral-neutral trials. One issue with this design, though, is that the analysis of disengagement trials assumed that all participants first engaged with threat to an equal degree. However, since anxious individuals may have an engagement bias as well as delayed disengagement from threat, it is important to separately measure these two effects so as not to confound them.

A variation of the dot-probe task has subsequently been developed to overcome this problem (Grafton & MacLeod, 2014; Rudaizky, Basanovic, & MacLeod, 2014). In this design, on each trial participants viewed a target image (a threatening or neutral scene) paired with a non-representational image (abstract art) and participants' shifts of attention toward and away from the location of the target image were measured. Specifically, these researchers presented an initial cue (a small red line oriented horizontally or vertically) before the presentation of the faces. This cue was presented either on the left or right side of the screen to secure participants' attention in the same location or opposite location to the target image. A disengagement trial was defined as a trial in which the target image was presented in the same location as the preceding cue, as this meant that participants had to disengage their attention from the target to respond to a subsequent probe in the distal location. An engagement trial, by contrast, was defined as a trial in which the target was presented in the opposite location to the preceding cue, as these trials measured whether participants shifted their attention toward the target. After the cue and faces were presented, a probe (similar in appearance to the cue) was presented in the locus of one of the faces and participants were asked to indicate whether the probe was the same or a different orientation to the cue. On 50% of trials, the probe appeared in the distal location to the target face and on 50% of trials, it appeared in the proximal location. Therefore, for engagement trials, faster RTs in the proximal probe position compared with the distal position, indicated that participants shifted their attention toward the target face. Importantly, these distal-proximal probe difference scores were compared between trials in which the target image was negative compared with when it was neutral, to measure if greater engagement toward threat occurred for anxious participants. Similarly, difference scores were used to measure the disengagement bias to test whether participants had greater difficulty shifting away from the target image and responding to the distally presented probe, compared with the proximal probe, when a negative target image was used compared with a neutral target image (Rudaizky et al., 2014). Both Grafton and MacLeod (2014) and Rudaizky et al. (2014) found that high trait anxious participants, compared with low trait anxious participants, had enhanced engagement biases and delayed disengagement biases for threat.

A recent study employed a similar design to measure engagement and disengagement biases for participants with low and high social anxiety (Grafton & MacLeod, 2016). Rather than using non-representational images, Grafton and MacLeod (2016) directly paired a negative and a neutral face on each trial. These researchers found that participants with high social anxiety had a greater engagement bias toward negative facial expressions compared with participants with low social anxiety. Social anxiety was not found to be associated with difficulties disengaging from threat. The use of this design marks an important development in the measure of threat biases as it provides a separate measure of engagement and disengagement biases. In addition, initial evidence indicates that social anxiety is characterised by enhanced engagement but not delayed disengagement from threat.

Attention Bias Modification

Since an attentional bias to threat is conceptualized as a maintaining factor for social anxiety, a growing body of research has attempted to develop therapeutic strategies and techniques to reduce this bias and, thus, reduce symptoms of social anxiety. This is known as attention bias modification (ABM; for a review, see Heeren, Mogoase, Philippot, & McNally, 2015). The most common method is a variant of the visual dot-probe task, in which probes nearly always (e.g., 95% of trials) follow non-threatening stimuli (e.g., neutral or happy faces). This task is designed to train individuals' attention away from threatening stimuli (e.g., angry or disgust faces) and, instead, toward neutral or positive stimuli. Although some studies have found that ABM results in reduced social anxiety (Amir et al., 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008; Heeren, Reese, McNally, & Philippot, 2012; Li, Tan, Qian, & Liu, 2008; Schmidt, Richey, Buckner, & Timpano, 2009), these results have not been replicated by other studies (Boettcher, Berger, & Renneberg, 2012; Boettcher et al., 2013; Carlbring et al., 2012; Heeren, Lievens, & Philippot, 2011; Julian, Beard, Schmidt, Powers, & Smits, 2012; McNally, Enock, Tsai, & Tousian, 2013). In fact, Boettcher et al. (2013) found that participants trained to attend to threat had the greatest improvements in social anxiety symptoms compared with the attend-positive and control condition, and Klumpp and Amir (2010) found that both attend-negative and attend-neutral conditions resulted in reductions in anxiety compared with a control condition. These mixed findings highlight the fact that the underlying mechanisms of this anxiety-related threat bias are not well understood. The purpose of the current thesis was, therefore, to understand the foundations of visual attention to threat associated with social anxiety. A better understanding of the bias can then guide techniques to ameliorate it and reduce social anxiety symptoms.

Mechanisms of the Threat Bias

Great strides in understanding the clinical significance of the threat bias in social anxiety have been made. However, the underlying mechanisms are not well understood. A particularly important issue is that it is not known whether these processes are driven by top-down attention, bottom-up attention, or selection history. In the literature review below, I consider four competing possibilities: (1) the threat bias is purely bottom-up in nature, (2) the bias is bottom-up but can be modulated by top-down attention, (3) the threat bias is largely driven by top-down attention, and (4) the bias is largely driven by selection history. Due to the limited research exploring these four possibilities in relation to social anxiety, the summary of research below also investigates attention to threat in the general population and threat biases for other anxiety disorders.

Is the Threat Bias Driven by Bottom-Up Attention?

The dominant view in the literature is that bottom-up threat detection has evolved due to its adaptive value (Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010; Lang, Bradley, & Cuthbert, 1997; LeDoux, 1996; LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). This makes good intuitive sense, since being able to rapidly attend to threat and respond (e.g., a fight or flight response) has a survival benefit (Pratto & John, 1991). Consistent with this perspective, research has found that humans have biases toward low-level perceptual features associated with threatening images (LoBue, 2014; LoBue & DeLoache, 2011; LoBue & Larson, 2010).

In support of this, using a visual search task, LoBue (2014) found that participants responded more rapidly to simple curvilinear shapes compared with similar rectilinear shapes. LoBue argued that a bias toward curvilinear shapes facilitates the detection of stimuli such as snakes, as well as spiders due to their curved legs, above the detection of other animals such as frogs or caterpillars. The detection of threat-relevant, low-level perceptual features is also enhanced by level of anxiety. For example, the curvilinear shape bias increased after participants watched a fearful film clip (LoBue, 2014). Similarly, both child and adult populations have been found to have biases toward angry face features (e.g., downward "V" shape of the brows) (LoBue & Larson, 2010), indicating that angry faces may be detected in a bottom-up manner. This research indicates that there may be a bottom-up feature- or object-based attentional system that guides attention to threat-relevant stimuli.

Nevertheless, the exact nature of the stimuli driving this bias is unknown, as threat can consist of a diverse range of features and objects (e.g., toward snakes, spiders, angry faces, bears, and crocodiles to name a few). It is, therefore, not known whether the threat-detection system is driven by a broad category of "threat" or is only associated with a discreet set of low-level features that are associated with some categories of threat (i.e., a curved shape is associated with snakes, spiders' legs, and a downward shaped mouth).

In addition, for the threat bias to be driven by bottom-up attention, we would also expect that threat detection would be invariant to task demands**.** That is, using a visual search task, it would be expected that search times for detecting threatening stimuli would not increase with greater numbers of distractors. This is not what has been found as, instead, search times for angry faces have been found to increase with added distractors (Eastwood, Smilek, & Merikle, 2001; Öhman, Lundqvist, & Esteves, 2001). This appears to indicate that the processing of threatening faces requires attentional resources (Vuilleumier & Righart, 2011), and is not purely bottom-up.

However, these research findings do not necessarily indicate that the threat bias is associated with top-down attention. Since visual information compete for representation in the visual cortex (Scalf, Torralbo, Tapia, & Beck, 2013), increasing display set-sizes, such as in the visual search task, results in greater stimulus competition. This leads to perceptual dilution, in which each stimulus is represented more weakly in the visual cortex (Scalf et al., 2013). Visual search results indicate that threat stimuli, just like other neutral but attention-grabbing stimuli (e.g., abrupt onsets or coloured objects), are affected by this competition. Therefore, although threatening faces do not result in “pop-out” effects, the bias may not reflect top-down attention. Instead, reduced detection of threat in the presence of greater numbers of distractors may simply reflect perceptual dilution. This body of research indicates that, although threat detection is affected by the number of stimuli in the visual field, it could still be driven by bottom-up mechanisms. The literature is, therefore, inconclusive. Social anxiety could be associated with an overactive bottom-up attentional system, resulting in a bias to threatening faces, or it could be associated with top-down attention. As a sidenote, considering that previous research has found separation in attentional resources between the right and left visual hemifields (e.g., Alvarez & Cavanagh, 2004), a possibility for further research would be to test attentional biases for individuals with high levels of social anxiety toward faces presented within a hemifield versus across hemifields, as perceptual dilution and competition may be greater for stimuli presented to the same hemifield than across.

Is the Threat Bias Driven by Bottom-Up Attention but Contingent on Top-Down Settings?

Although there is some evidence for bottom-up biases to threat, it is likely that the threat bias associated with social anxiety is affected by top-down control. This is because attention to low-level visual stimuli (e.g., colours and abrupt onsets) can be eliminated under differing top-down settings (Folk, Remington, & Johnston, 1992). This contingent capture effect has also been demonstrated with emotional faces. With a non-clinical population, Barratt and Bundesen (2012) employed a flanker task in which participants responded to the emotion of a central positive or negative schematic face accompanied by positive, negative, or neutral distractors faces. These researchers found slower RTs to respond to the positive face when flanked by negative distractor faces compared with neutral or positive distractor faces, indicating involuntary capture of attention by the negative faces. In a second experiment, Barratt and Bundesen (2012) employed target letters and found no slowing effect from negative face distractors. This suggests that attention to negative faces is not involuntary but dependent on attentional control settings (i.e., whether participants were searching for a face or letter). Reeck, LaBar, and Egner (2012) tested the role of top-down control settings for emotional faces for participants with low and high trait anxiety. In this task, participants responded to the orientation of a Gabor stimulus. Prior to its presentation, participants could receive an informative cue, indicating the location of the target Gabor. This provided a measure of top-down attentional guidance. Before the onset of the target, participants could also be presented with a neutral or fearful face presented either validly (in the location of the to-be-presented target Gabor) or invalidly (in the opposite location of the to-be-presented target Gabor). Differential responding on trials with the fearful face, compared with the neutral face, would indicate bottom-up attentional capture to fear. These researchers found an overall effect of speeded responses to the Gabor when participants received a top-down location cue. There was also an overall cueing effect (faster RTs on validly-cued compared with invalidly-cued trials) for the face. However, high trait anxious participants only demonstrated a cueing effect for the neutral face trials and not when there was a fearful face. Instead, the high trait anxious participants showed slowed responding on the valid fearful-face trials. This is somewhat surprising and Reeck et al. proposed that it could be because the anxious participants may have experienced increased interference from the fearful faces, or the fearful faces could have exhausted attentional resources needed to respond rapidly on the task. These results could indicate bottom-up capture (resulting in a slowing effect) from the fearful faces for high trait anxious participants. Critically, this effect was overridden when a top-down cue was provided, as high trait anxious participants no longer had differential responding to the fearful face. This provides support for contingent capture effects, as anxious participants can overcome their bottom-up biases to fear when given a top-down goal.

One theoretical account of trait anxiety that encapsulates these processes is Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which theorises that anxious individuals have an imbalance between top-down and bottom-up attention, with increased influences from bottom-up capture of attention and poorer top-down control. Particularly in stressful situations, anxious individuals are likely to have difficulty inhibiting attention toward task-irrelevant stimuli, shifting attention between tasks, as well as updating information (e.g., reading and operation spans). The above argument indicates that top-down attention is involved in attentional orienting to threat, as top-down control can override attentional capture and anxious individuals may have some deficits in top-down attentional control.

Is the Threat Bias Driven by Top-Down Attention?

An underlying assumption in the literature has been that threat biases are bottom-up in nature. Although attention to threat generally (e.g., to spiders, snakes, and angry faces) may have bottom-up contributions, it is possible that the threat bias associated with *social anxiety* could be driven by top-down attention. As discussed previously, top-down attention is driven by the goals of the individual. In addition, negative beliefs about the self and others are core factors in the conceptualisation of social anxiety (Clark & Wells, 1995; Rapee and Heimberg, 1997). These beliefs may result in top-down goals, guiding the deployment of attention to sources of attention that confirm those beliefs. For example, the belief that "everyone thinks I'm stupid" may result in top-down guidance of attention to critical facial expressions that confirm that belief. As discussed previously, to determine whether the threat bias is bottom-up or top-down in nature, researchers have employed an additional WM load task to deplete top-down attentional resources. WM load selectively impairs top-down attention but not bottom-up attention (Jonides, 1981). If an attentional bias to threat is eliminated by the addition of a high WM load task, it would indicate that the bias is associated with top-down attention, whereas if the threat bias is unaffected by the addition of load, it would indicate that the threat bias is bottom-up.

Researchers employing WM load tasks have found some evidence that attentional biases can be overcome under high WM load (Pessoa, McKenna, Gutierrez, & Ungerleider 2002; Van Dillen & Koole, 2009). For instance, Van Dillen and Koole (2009) employed a variation of the Stroop paradigm, in which participants viewed faces of varying expressions, and were asked to indicate the gender of the faces. This study found that, compared with happy faces, angry faces resulted in slower gender naming, but only under low load. This suggests that the angry face captured attention under low load, but that this effect was eliminated when top-down attentional resources were taxed with the WM task. Since top-down but not bottom-up attention shares resources with WM, this implicates top-down attentional processes in the attentional effect of the angry face. However, this body of research has looked at interference effects from threatening stimuli that are presented individually at an attended location rather than the capture of attention to the spatial location of a stimulus that is in competition with other stimuli elsewhere in the scene. Spatial attentional capture in the context of multi-item scenes is particularly important to understanding threat biases for socially anxious individuals (e.g., to understand visual attention to audience members when giving a speech or when in public). Therefore, the research in this thesis examined spatial attentional capture in the context of competition between simultaneously-presented threatening and non-threatening stimuli.The possibility that spatial attentional capture may be driven by top-down attentional mechanisms was explored by Pessoa and Adolphs (2010). These researchers argued against the simplistic view that affective stimuli are exclusively processed automatically by subcortical structures. Instead they emphasised the network of cortical and subcortical structures (e.g., amygdala, orbitofrontal cortex, anterior insula and anterior cingulate cortex) that allocate resources to prioritise processing of affective or motivationally significant stimuli. By this account, top-down structures are involved, even in rapid orienting toward stimuli. This is consistent with a view of that top-down attentional control results from processing from frontal regions back into earlier visual regions, which can lead to rapid attentional orienting to goal-driven stimuli.

This is supported by findings from Purkis, Lester, and Field’s (2011) visual search task study, which explored attentional capture by spiders and *Doctor Who* stimuli. Whereas it can be argued that attending to spiders may rely on specially evolved, bottom-up mechanisms, it is highly implausible that *Doctor Who* stimuli would have the same evolutionary value. Instead, it was hypothesised that, if attentional biases can be driven by a contextual or top-down motivational value, then an ardent *Doctor Who* fan should demonstrate a bias toward *Doctor Who* stimuli. This is exactly what this research found. Individuals with spider fear had slowed RTs when a distracting spider image was present and *Doctor Who* fans had slowed RTs when *Doctor Who* stimuli were present. This suggests that top-down factors, such as motivational value that does not stem from evolutionary significance, can drive attentional biases. Similarly, physiological hunger is associated with a temporary attentional bias toward food (Mogg, Bradley, Hyare, & Lee, 1998). Since bottom-up processes are conceptualised as being invariant to contextual factors, it would not be expected that an evolved food bias would vary based on the individual’s motivation for food.

Similarly, heavy drinkers have a bias toward alcohol cues (Townshend & Duka, 2001), which does not have an associated survival value. This body of research is, therefore, consistent with the proposition that attentional biases are influenced by a flexible top-down system rather than relying on bottom-up mechanisms exclusively.

Finally, Judah, Grant, Lechner, and Mills (2013) attempted to test the role of top-down attention for threat-related biases associated with social anxiety. In this study, participants completed a dot-probe task with happy, disgust, and neutral facial expressions under three conditions: no, low, and high WM load. Judah et al. (2013) attempted to measure late stages of attention by presenting stimuli for long durations (1000ms). These researchers concluded that socially anxious individuals avoided disgust expressions under no WM load and had difficulty disengaging attention from disgust expressions under high WM load. However, this study did not separately analyse engagement and disengagement biases. Since participants first need to engage with an image before disengaging from it, any attempts to measure the disengagement bias was confounded by engagement effects. Further research is, therefore, needed to confirm these findings.

Is the Threat Bias Driven by Selection History?

Recently Peschard and Philippot (2016) theorised that selection history may have an important role in attentional biases toward threat for social anxiety. The framework posited by Peschard and Philippot (2016), emphasised the interplay between various factors of attention, which determine attentional selection for individuals with social anxiety. These factors include task goals, attentional control, WM, the emotional and motivational value of the stimulus, long-term memory, stimulus salience, and selection history. As discussed previously, selection history has been found to be an important mechanism that drives attention. However, Peschard and Philippot did not test this possibility that they proposed, and, to our knowledge, no other research has tested the role of selection history for detecting facial expressions with either an unselected sample or with individuals with social anxiety. The research in this thesis rectifies this gap.

Summary and Links to the Present Thesis

Several decades of research indicate that a bias toward threatening visual information, such as angry and disgust facial expressions, is a critical maintaining, and possibly aetiological, factor contributing to social anxiety symptoms. However, this bias is not well understood. The research reviewed in this chapter indicates that bottom-up attention may be a part of an important evolutionary system that allows individuals to rapidly orient to threat. Socially anxious individuals could, therefore, have an overactive bottom-up system that more readily deploys attention to threat compared with non-anxious individuals. However, the evidence shows that it is likely that threat biases are affected by top-down factors. That is, the research reviewed either indicates that socially anxious individuals could have deficits in top-down control or that the threat bias itself could be driven by a chronic top-down set to attend to threat. Finally, selection history may also contribute to the threat bias but there is, to our knowledge, no previous research testing this possibility. Indeed, if socially-anxious individuals are repeatedly and frequently selecting threatening information, then this highlights a potential role for selection history in contributing to the bias.

Chapter Five tests the roles of top-down attention, bottom-up attention, and selection history in humans' ability to orient to emotional faces. Chapter Six then extends on this research by investigating whether the ability to use top-down attentional control to orient to emotional faces is impaired for individuals with high levels of social anxiety. Next, Chapters Seven and Eight investigate whether the bias to threat for individuals with high social anxiety is associated with top-down or bottom-up attention. A dot-probe design was employed in the experiments throughout this thesis as the paradigm allows for the measurement of visual attentional shifts across space, it is a widely-used and established measure of spatial attention

(Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; MacLeod et al., 1986), and allows for the separate measurement of engagement and disengagement attentional biases. In sum, the research of this thesis lays the groundwork for understanding the underlying mechanisms of the threat bias so as to build our knowledge of social anxiety and guide further treatments.

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Chapter Five. Searching for Emotion: A Top-Down Set Governs Attentional Orienting to Facial Expressions

Chapter Overview

Chapter Five investigates the underlying mechanisms of attentional orienting to emotional faces. Specifically, this chapter explores whether attention to faces is associated with top-down attention, bottom-up attention, or selection history. This is tested across four experiments using an adult, non-clinical sample. This chapter provides critical information on the foundations of attentional orienting. Further chapters then test how these attentional processes differ for individuals with high levels of social anxiety.

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- **Delchau** proposed the project.
- **Delchau** designed the experiments with contributions from Goodhew, Christensen, Lipp, and O'Kearney.
- **Delchau** coded the computer tasks.
- **Delchau** collected the data for Experiment 1. Undergraduate students Bandara, Tan, and Yabuki collected the data for Experiments 2, 3, and 4.
- **Delchau** analysed the data, with advice from Goodhew.
- **Delchau** and all other authors contributed to discussions surrounding interpretation of the data.
- **Delchau** produced the tables and figures.

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Searching for Emotion: A Top-Down Set Governs Attentional Orienting to Facial Expressions

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Abstract

Research indicates that humans orient attention toward facial expressions of emotion. Orienting to facial expressions has typically been conceptualised as due to bottom-up attentional capture. However, this overlooks the contributions of top-down attention and selection history. In the present study, across four experiments, these three attentional processes were differentiated using a variation of the dot-probe task, in which participants were cued to attend to a happy or angry face on each trial. Results show that attention toward facial expressions was not exclusively driven by bottom-up attentional capture; instead, participants could shift their attention toward both happy and angry faces in a top-down manner. This effect was not found when the faces were inverted, indicating that top-down attention relies on holistic processing of the face. In addition, no evidence of selection history was found (i.e., no improvement on repeated trials or blocks of trials in which the task was to orient to the same expression). Altogether, these results suggest that humans can use top-down attentional control to rapidly orient attention to emotional faces.

Keywords: selective attention, spatial attention, dot-probe, facial expressions, emotion.

Searching for Emotion: A Top-Down Set Governs Attentional Orienting to Facial Expressions

You see two people before you; one with an angry expression and one with a happy expression. Which face captures your attention? And why? Despite decades of research on attentional orienting to emotional faces, the answer to these questions remains elusive. This is an important question to address because the ability and tendency to orient to faces of particular expressions have implications for a person's social functioning, and are linked to disorders such as social anxiety (e.g., Grafton & MacLeod, 2016; Lin, Hofmann, Qian, Kind, & Yu, 2016; Pishyar, Harris, & Menzies, 2004). The purpose of the current study, therefore, was to determine the relative contributions of different core mechanisms of attention to emotional face processing. The necessity of visual selection is ever-present as we are constantly bombarded with visual information, only a small amount of which our cognitive systems can process at any given moment (e.g., Broadbent, 1958; Neisser, 1967; Treisman, 1960). Attention plays an important role in selecting particular information for processing at the expense of other information. But what mechanisms guide selective attention? Traditionally, such mechanisms have been categorised as either top-down or bottom-up. Top-down attention refers to the voluntary allocation of attention toward objects, features, or spatial locations (e.g., searching for a friend's blue coat in a crowd), whereas bottom-up attention refers to the involuntary capture of attention by physically salient stimuli (e.g., a flashing light) (Corbetta & Shulman, 2002). A third mechanism of selective attention has also now been recognised; selection history (Awh, Belopolsky, & Theeuwes, 2012). That is, attention can be captured by a visual stimulus due to its past selection or reward history, even if it no longer matches the individual's top-down goals. Historically, research on attentional orienting has typically assumed, either implicitly or explicitly, that orienting is driven by bottom-up factors. However, theory and research from the field of visual attention indicates that the focus of attention at a given point in time is a product of both top-down and bottom-up processes. This challenges the assumption of bottom-up factors driving attentional orienting to faces as, instead, it seems likely that top-down processes are implicated. Moreover, more recently, the role of selection history in attentional orienting has been distinguished from 'pure' top-down processes. Therefore, the present study systematically examined the relative contribution of top-down attention, bottom-up attention, and selection history in orienting toward emotional faces.

Bottom-Up Attention

A common conceptualisation of attentional selection is that preferential attention is directed toward the most salient visual stimuli, locations, or visual features that evoke the strongest neural response within the visual field (Desimone & Duncan, 1995; Koch & Ullman, 1985). A widely-held view in the literature is that emotional faces capture attention in a bottom-up manner as they are more salient than neutral faces. Traditionally, it has been posited that *threatening* expressions hold special significance for attentional selection (Hansen & Hansen, 1988; Lipp, Price, & Tellegen, 2009a, 2009b). For instance, in Hansen and Hansen's (1988) classic face-in-the-crowd experiment, participants' reaction times (RTs) to detect an angry face did not increase with increasing set size, indicating that angry faces "popped-out" of the array (however, see Purcell, Stewart, & Skov, 1996, for an alternative account of this result). This is consistent with an evolutionary account that being able to respond to threat through bottom-up processing is rapid and automatic and, therefore, adaptive as it allows individuals to respond quickly and protect themselves (LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). However, other research has suggested that attention is not specifically oriented towards threat, but towards emotion more broadly. For example, studies have also shown a *happy* face advantage (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011), though other research has found that happy and angry face advantages in visual search depend on the type of face database employed (Savage, Lipp, Craig, Becker, & Horstmann, 2013*).* The lack of consistent findings may indicate that attentional capture by emotional faces is associated with low-level perceptual differences across face databases, rather than bottom-up attention to the expressions themselves. Since bottom-up attentional orienting is conceptualised as context-invariant, the diversity of results observed in this literature undermines the notion that facial expressions represent a basic stimulus property that consistently orient attention in a bottom-up way. While there may be some role for bottom-up processes in orienting to faces of particular facial expressions, there is reason to believe that other factors are also at work.

Top-Down Attention

There are issues with bottom-up attentional accounts of orienting to faces of different emotional expressions, as described above. Moreover, a large body of research using basic visual features also indicates that top-down attention has a powerful influence over the selection of stimuli in our visual field, as described in this section. At the very least, this likely implicates a role for the interplay between top-down and bottom-up attention, if not for a dominant role of top-down attention in attentional orienting to faces.

The power of top-down attention is demonstrated by the classic and robust endogenous cueing procedure described by Posner (1980). In this task, on each trial, a cue (e.g., an arrow or digit) is used to inform participants of the likely location of a to-be-presented target. The cue is not intrinsically salient, as is the case for exogenous attentional cueing. Yet participants reliably utilise the informativeness of the cue, as evidenced by the fact that they respond faster and more accurately to the target in the cued location compared with the un-cued location (Posner, 1980; Theeuwes & Van der Burg, 2007). This is thought to reflect participants using their top-down set to guide attention to a location in space.

In addition to top-down guidance of attention to spatial locations, top-down attention can also be guided to particular object features. According to contingent capture theory, visual cues, that would otherwise be salient in a bottom-up fashion, will only capture spatial attention if they match the top-down attentional set of the participant. In a seminal demonstration of this, Folk, Remington, and Johnston (1992) conducted an experiment in which participants responded to the presence of an “X” or “+” in a stimulus array. These targets could either be defined by onset, whereby a single target would appear on each trial, or by its red colour amongst white distractors. On some trials, a cue (four dots surrounding a placeholder) was presented prior to the onset of the target. Like the target, the cue was defined by either onset or colour. Folk et al. (1992) found a typical cueing effect. That is, valid cues (which signalled the correct location of the to-be-presented target) resulted in faster responding to the target, while invalid cues (which signalled an incorrect location) resulted in slowed responding. However, cueing *only* occurred if the cue matched the properties of the target. Therefore, when the target was defined by onset, onset cues affected performance, and when the target was defined by colour, colour cues affected performance. This indicates that attentional orienting is driven, at least in part, by top-down attentional settings. Decades of subsequent research have supported this notion of contingent capture, such that salient cues only capture attention if they match a participant’s top-down set (for a review, see Folk & Remington, 2010).

The vast majority of research on top-down attention has focussed on top-down sets for simple features (e.g., onsets and colours). However, there is some evidence that this contingent relationship between one’s top-down set and the properties that capture attention extends to more complex stimuli, including faces (Barratt & Bundesen, 2012; Goodhew, Kendall, Ferber, & Pratt, 2014; Wyble, Folk, & Potter, 2013). Barratt and Bundesen (2012) employed a flanker task in which participants responded to the expression of a central schematic face surrounded by distractor faces. Participants responded more slowly to happy face targets when they were flanked by negative faces compared with positive or neutral faces, indicating involuntary capture of attention by negative faces. By contrast, when the central target was a letter and not a face, participants' attention was not captured by negative face distractors in this way. This could reflect, in the latter case, that participants had a top-down set for a letter, and not the faces, thereby undermining the facial expression flanker's ability to capture their attention. This suggests that spatial attentional capture by faces is dependent on top-down attention. However, it is unclear what constituted participants' top-down set on trials when the target was a face. That is, participants could have had a top-down set for the generic category of "face" (or even a broader category, such as "complex object"), but equally it could have been "emotional face". There is no evidence that it was an emotion-specific top-down set (e.g., "happy face") as, if this set could be instantiated, we would expect that the negative face flankers would have been excluded from attentional capture. Here, therefore, we examined whether participants could adopt a top-down set for a specific emotional expression and, if so, whether this was driven by simple features or more holistic processing. Furthermore, we examined whether bottom-up processing of emotional expressions would interfere with the operation of any top-down set.

Selection History

In addition to top-down and bottom-up attention, a third mechanism of attention requires consideration: selection history. Selection history recognises that visual attentional capture can occur based on the individual's selection and reward history, which may differ from their current top-down goals. For example, Maljkovic and Nakayama (1994) found that when participants made speeded responses to a target defined by colour or spatial frequency cues, RTs were faster when the same target repeated across two trials than when it switched. This difference occurred even when participants knew with 100% certainty the identity of the target on the upcoming trial, indicating that selection history can differ from one's current goal and guide attention. Some researchers have gone as far as to argue that participants cannot use top-down attention, and that all previous evidence for top-down effects can be explained purely by selection history (Theeuwes, 2013; Theeuwes, Reimann, & Mortier, 2006). More recent evidence, though, has shown that this is not the case; for example, when more complex arrays are employed, attention is guided by the participant's top-down set (Belopolsky & Awh, 2016).

Experimentally, there are several ways to distinguish between guidance by top-down attention and selection history. Firstly, throughout a block of trials, the target can be varied on a trial-by-trial basis (e.g., 200 trials in which the target is either red or green and is signalled at the start of each trial), and performance on trials for which the target type repeats across two trials versus when the target switches can be compared. Enhanced performance to the target on repeat trials, compared with switch trials, reveals an effect of selection history (also known an intertrial priming). A second method to measure selection history is to compare blocked versus mixed manipulations of the top-down set. That is, when the property that defines a target is fixed across a series of trials constituting an experimental block (e.g., search for a red target for 100 trials, and then a green target for 100 trials), then both top-down and selection-history processes are thought to contribute to attentional orienting. In contrast, in an intermixed block, the contribution of selection history is substantially diminished, providing a measure of top-down contributions (though note that, selection history effects can only be eliminated if the target never repeats across trials). Since top-down contributions can be considered as constant across the blocked versus mixed conditions, the impact of selection history can be gauged by comparing the blocked (selection history strong) and mixed (selection history weak) designs (Awh et al., 2012; Büsel, Voracek, & Ansorge, 2018). Importantly, top-down attentional orienting can operate in mixed designs (Belopsolsky

& Awh, 2016, Schoeberl, Goller, & Ansorge, 2019; Theeuwes, 2018). Since selection history has been found to play a critical role in attentional orienting to basic stimuli, it may also be central to understanding attentional orienting to faces. To our knowledge, no previous research has tested the relative contributions of top-down attention, bottom-up attention, and selection history to orienting to emotional faces.

Summary and Present Study

In sum, the extant empirical literature identifies three main categories of attentional guidance: top-down, bottom-up, and selection history. Previous studies on attentional orienting to facial expressions have purported that bottom-up mechanisms are responsible for attentional orienting. More recently, the importance of top-down attention toward faces has begun to be recognised but has not been systematically tested. The purpose of this study, therefore, was to test whether humans can instantiate a top-down set for a facial expression, and test whether this can guide attentional orienting in a way that is not accounted for by selection history and that overrides any bottom-up capture that may be present. These questions were assessed across four experiments.

Experiment 1

Experiment 1 used a modified dot-probe design with angry, happy, and neutral photographic face stimuli. In this task, participants were given a top-down cue (the words “Happy” or “Angry”) to indicate the emotional expression they should orient towards. These cues could vary from trial-to-trial. Participants viewed two faces, one to the left and one to the right of fixation, and a probe letter replaced one of the faces. Valid trials were those in which the probe subsequently appeared in the same location as the cued face, whereas invalid trials were those in which the probe appeared in the opposite location to the cued face. The majority of trials were valid (75%). Faster RTs to the probe in the location of the cued face (valid) compared with the opposite location (invalid) indicated that participants could rapidly orient to that face. This design was employed because it allowed measurement of bottom-up biases towards faces via a widely-used and established measure of spatial attention (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; MacLeod, Mathews, & Tata, 1986). Moreover, since the same stimuli were presented on valid and invalid trials, cueing effects were not confounded by differences in responding when emotional stimuli were present compared with when not present (e.g., slowed responding or "freezing" can occur in the presence of threat but not in the presence of neutral-neutral trials).

It was predicted that, if participants instantiate a top-down set for happy and angry facial expressions, then they should show a cueing effect. By contrast, if attention toward either happy or angry facial expressions is driven by bottom-up attention, faster RTs will be found on trials in which the probe is presented in the locus of the emotional face, regardless of the cue. Finally, if there is an effect of selection history, a greater cueing effect will be found for trials in which the to-be-searched for facial expression repeats compared with when it switches.

Method

Participants. Forty-six participants were recruited via the Australian National University online sign-up portal, online Australian National University advertising portals, and flyers on campus. Ethical approval was provided by the Australian National University Human Research Ethics Committee (protocol number: 2014/534). Participants provided written, informed consent. Using G-Power[2], it was calculated that, to detect a small-medium effect size (f = .15) with 90% power, assuming a correlation of 0.6 between conditions, a minimum sample size of 42 was required (see Results section: after exclusions, 43 participants were included in the analyses). Restrictions were that participants were Caucasian, aged 18-30 years, with normal or corrected-to-normal vision. Caucasian participants (self-reported) and Caucasian images were employed to control for the cross-race effect (for a review, see Young, Hugenberg, Bernstein, & Sacco, 2012), in which faces of other-race individuals can be processed differently to those of one's own race. Participants' ages ranged from 18 to 30 years (*M* = 21.59, *SD* = 3.44); 44 participants were right-handed, 2 were left-handed, 32 were female and 14 were male. The experiment took participants approximately 45 minutes to complete and each was offered either course credit or $10 cash.

Experimental stimuli and apparatus. This experiment was conducted in a dimly lit room. Stimuli were presented on a liquid crystal display (LCD) monitor running at a 60Hz refresh rate. Viewing distance was set with a chinrest at 44cm. Stimuli were programmed in Matlab using the Psychophysics Toolbox (Brainard, 1997). The background was set to black. Images of faces were taken from the NimStim database (Tottenham et al., 2009). The Nimstim database was selected because it has faces with closed-mouths. That is, closed-mouth expressions were chosen to eliminate attentional capture by teeth (Horstmann, Lipp, & Becker, 2012). In addition, the Nimstim database has been validated; recognition of facial expressions was 84% proportion correct for the closed-mouth angry faces, 92% for closed-mouth happy faces, and 91% for closed-mouth neutral faces (Tottenham et al., 2009).

The selected images consisted of Caucasian faces posing with closed-mouth neutral, happy, and angry expressions (Tottenham et al., 2009). Further exclusions were made due to the incorrect size of one of the images (model 1), confounding facial hair (model 31), and not having a closed-happy face image (model 27). Therefore 22 models (7 females and 15 males) were included, each providing happy, neutral, and angry expressions. During the experiment, each image subtended 9.4° x 12.1° of visual angle, with a gap of 9.4° of visual angle between the two images. On each trial, the word cue ("Happy" or "Angry") was presented in white, size 18, Helvetica font. In addition, the probe letter ("E" or "F") was presented in white, size 18, Helvetica font.

Procedure. The conditions included happy-neutral, happy-angry, and angry-neutral face pairings. It was always either the happy or angry face that was cued, either validly (the target was in the cued location), or invalidly (the target was in the non-cued location). In this design, the main analysis was a 2 (target face: angry or happy) x 2 (distractor face: emotional or neutral) x 2 (cue: valid or invalid) factorial repeated-measures ANOVA.

An additional "incorrect cue" condition was included. Here, pairs of faces were happy-neutral or angry-neutral. The cue did not match the faces presented, and the probe appeared in the locus of the emotional expression. This condition was included as an additional test to ensure that participants' attention would not be captured by an emotional face that did not match their top-down set. An example of this type of trial would be when participants received a cue of "Angry" but were then presented with a happy-neutral face pair. The incorrect cue condition was not part of the main factorial analysis, since it did not have a corresponding valid condition, and was instead analysed separately.

Participants completed a demographic questionnaire and then the experimental computer task. The demographic questions assessed age, gender, handedness, and cultural/racial identity. The computer task included 50 practice trials and then 360 experimental trials with 8 rest breaks. Trials were randomised throughout the experiment with the constraint that the cued face was predictive of the probe location on 75% of trials. A break-down of trials was as follows: 135 trials were either valid happy-neutral (cued happy) or angry-neutral (cued angry) face pairs; 135 trials were either valid happy-angry (either validly cued happy or angry) face pairs; 30 trials were invalid happy-neutral or angry-neutral face pairs; 30 trials were invalid happy-angry face pairs; and 30 trials were incorrectly cued happy-neutral or angry-neutral face pairs. The cue (happy or angry) within each condition was randomised, such that an approximately equal number of trials were included for each cue. On each trial, the two images presented were of the same model so that they were matched for facial properties. The identity of the face on each trial was randomly selected with the constraint that the same proportion of male and female images were included in each condition.

On each trial, participants were presented with a blank black screen for 500ms with a centrally presented fixation cross (see Figure 1). The cue word (“Angry” or “Happy”), written in the centre of the screen in white, was then presented for 1000ms and was followed by a blank screen with a fixation cross for 1000ms. Participants were instructed to orient their attention to the cued facial expression when it appeared. The faces were presented for 200ms, one to the left and one to the right of fixation. This timing was selected with the intention of providing sufficient time for participants to shift their attention toward one of the face locations without being able to make multiple saccades. After face offset, a probe (the letter “E” or “F”) was presented for 300ms in the locus of one of the faces. Participants were asked to indicate the identity of the probe (an E or F), with a keyboard press, as accurately and quickly as possible. Once participants made a keyboard press, the next trial began.

It is important to note that this was a speeded task, and participants were *not* instructed to withhold their response during the probe. Instead, the probe duration was sufficiently short that meaningful responses would unlikely be made during this time (indeed 200-300ms is a commonly-employed criterion for excluding artifactual RTs from identification responses). The advantage of having a time-limited probe duration (rather than shown until response) is that it more strongly compels attention to be in the probe location, and a greater cost is incurred if it is not (since it subsequently disappears). Thus, the design is most sensitive to measuring the spatial allocation of attention. Converging evidence for this is provided by previous research that has used such a design and found robust attentional biases (see e.g., Cox, Christensen, & Goodhew, 2017).

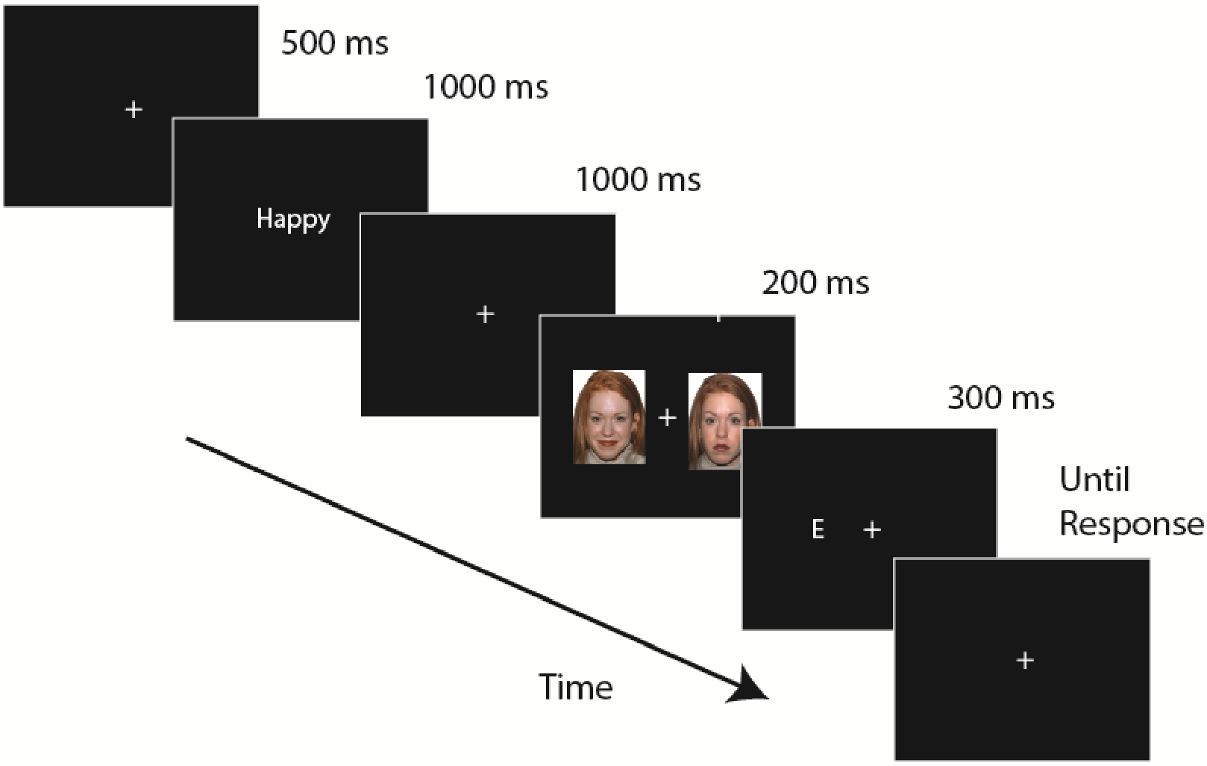


Figure 1. Schematic of a trial. On this trial, the cue is “Happy”, which is followed by a happy-neutral face pair, and the probe is validly presented in the locus of the happy face. Note that participants were instructed to respond as quickly and accurately as possible as soon as they could identify the probe.

Results and Discussion

Two participants’ data were excluded due to chance-level accuracy (49.9% and 49.7%) on the probe detection task and one participant’s data were excluded due to unusually slow RT (z-score > 3.29). Therefore, data from 43 participants were included in the final analyses. Trials in which participants made an invalid key press (i.e., hit a key that was not “E” or “F”) or responded quicker than 100ms or slower than 2.5 standard deviations from their average RT were also excluded. This accounted for 2.3% of participants’ data. Accuracy and RTs for the correct trials were then calculated. Mean accuracy on the probe task was 91%

(*SD* = 6.6%) and mean RT was 674.9ms (*SD* = 103.7ms)[3]. Full raw data for all experiments are available here: [https://osf.io/8zt2a/]).

Cueing effect. Although the RT data are of primary interest to the analyses, accuracy was first assessed to test for any potential speed-accuracy trade-off. To assess accuracy, a 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA was conducted. No significant effects were found (ps $\geq$ .135).

To test whether participants demonstrated a cueing effect, and if the cueing effect differed as a function of the target and distractor facial expressions, a 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA on RT was conducted. A significant effect was found for type of distractor face, $F(1, 42) = 6.04$, $p = .018$, $\eta^2 = .126$, such that participants were faster at responding to the probe when the distractor was neutral (i.e., happy-neutral and angry-neutral face trials) (M = 670.9ms), compared with when the distractor was emotional (i.e., happy-angry face trials) (M = 679.4ms). This result was qualified by an interaction between target face and distractor face, which was trending toward significance, $F(1, 42) = 3.84$, $p = .057$, $\eta^2 = .084$. Further analyses revealed that participants were significantly faster at responding to the probe when a happy-target face was paired with a neutral face (M = 664.9ms) compared to when paired with an angry face (M = 679.6ms), $F(1, 42) = 9.48$, $p = .004$, $\eta^2 = .184$. By comparison, RTs to the probe did not significantly differ when the target angry face was paired with a neutral face compared with when paired with a happy face, $F(1, 42) = .27$, $p = .607$, $\eta^2 = .006$.

However, the interactions between distractor face and cue validity ($p = .945$) and between the target face, distractor face, and cue validity ($p = .777$) were not significant, indicating that the cueing effects were not altered by the type of distractor face or target face. This suggests that, regardless of whether participants were responding to the validly or invalidly presented probes, participants had slower RTs in the presence of an angry face (either when the angry face was the target or the distractor face). This may reflect a freezing effect in the presence of threat, which leads to slowed responses when angry faces were present (Roelofs, Hagenaars, & Stins, 2010).

Most importantly, a significant cueing effect was found, $F(1, 42) = 7.36$, $p = .010$, $\eta^2 = .149$, as participants were faster on valid trials (M = 666.4ms) compared with invalid trials (M = 683.9ms) (see Figure 2). No other significant effects were found (ps $\geq .107$). In summary, these results indicate that participants could reliably shift their attention toward both the happy and angry face in response to top-down cues.

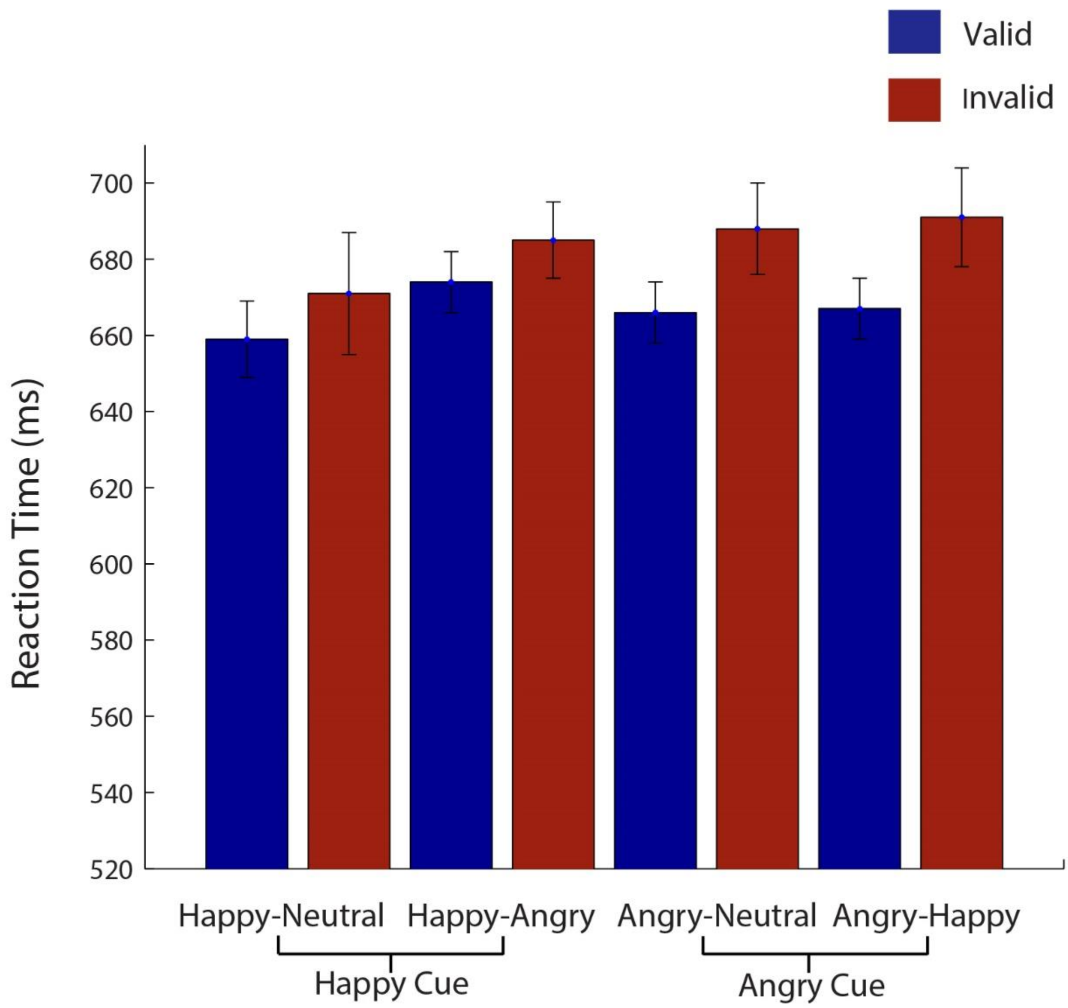


Figure 2. Reaction data for Experiment 1. Within-subjects 95% confidence intervals were calculated using Morey's (2008) correction for within-subject designs.

Incorrect-cue trials. For incorrect-cue trials, the cue could either be "Happy" in the context of an angry-neutral face pair or "Angry" in the context of a happy-neutral face pair. This condition assessed whether participants would only orient to an emotional face when it matched their top-down set or whether bottom-up emotional capture of attention would occur toward the un-cued emotional face. Specifically, quick responding to the probe replacing these un-cued emotional faces would indicate bottom-up attentional capture. Conversely, if responding was slower than the valid conditions, it would indicate that participants were able to inhibit attentional capture by these emotional faces. To test this, the valid happy-neutral and angry-neutral data, which were previously used in the main analysis, were also analysed here.

A 2 (target face: happy or angry) x 2 (cue: valid or incorrect-cue) ANOVA was conducted. A significant cueing effect was found, $F(1, 42) = 5.03$, $p = .030$, $\eta^2 = .107$, with participants responding faster on valid trials ($M = 662.1$ms) compared with invalid incorrect-cue trials ($M = 673.7$ms). No other significant effects were found (ps $\geq .294$). This suggests that the correct cue provided an advantage in responding to the probes replacing emotional faces over and above responses following incorrect cues. In other words, top-down attention provided benefit over and above the possible effects of bottom-up attentional orienting to emotional faces.

Selection history effect. To measure the effect of selection history, cueing effects were compared between repeat and switch trials. Switch trials were those in which participants were asked to attend towards an expression that differed from the one attended to on the previous trial whereas, on repeat trials, participants were asked to attend to the same expression as on the previous trial. Trials were only included in these analyses if the previous trial was valid as, for valid trials, shifting toward the cued face was "rewarded" as the probe was presented in the locus of the cued face.

To test the effect of selection history, a 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) x 2 (repetition: repeat or switch) ANOVA was conducted. The interaction between cue and repetition was not significant (p = .737), as the cueing effect for repeat trials (M_{valid} = 665.6ms; M_{invalid} = 682.2ms) was not significantly larger than the cueing effect for switch trials (M_{valid} = 667.8ms; M_{invalid} = 681.9ms). In other words, there was no evidence for selection history effects in the present study[4]. Since the results of the selection history analysis failed to reject the null hypothesis, the null hypothesis statistical testing was supplemented with Bayesian analysis performed in JASP with the default priors. This revealed that the BF_{10} factor was <1 for the interaction between cue validity and interaction. A BF_{10} quantifies the ratio of evidence in favour of the alternative versus the null hypothesis (Jarosz & Wiley, 2014), and therefore there was greater evidence *in favour* of the null hypothesis in this experiment. This converges with the results of the hypothesis testing.

To summarise, Experiment 1 results suggest that participants could employ top-down attention to orient toward both angry and happy facial expressions, as evidenced by significant cueing effects in response to top-down cues. In addition, cueing effects did not significantly differ between trials when an emotional face (happy or angry) was paired with a neutral face or when happy and angry faces were paired together. Furthermore, one of the conditions in this study (incorrect-cue trials) cued an expression that was not subsequently presented. Responses in this condition were slower than responses following correct cues. This indicates that participants used the top-down cue to reliably orient attention to the cued face. Finally, no evidence for selection history effects was found. These results provide support for the notion that top-down control can be used to guide attention to facial expressions. While a contribution of bottom-up attentional capture cannot be ruled out, no evidence for bottom-up attentional capture was found (this issue was addressed explicitly in

Experiment 3, where it was confirmed that bottom-up attentional capture did not play a role). This, in conjunction with the evidence that valid cues were providing orienting advantage over incorrect cues on incorrectly cued trials supports the conclusion that the present results do indeed reflect top-down attentional orienting.

Experiment 2

Although Experiment 1 found that participants could shift their attention toward the cued happy and angry faces, the specific properties of the faces used to do so remain an open question. That is, do participants rely on specific facial features (e.g., the mouth or eyes) to shift attention to cued happy or angry faces or do they form a holistic top-down set for those facial expressions? Research has found that inverting a face disrupts the ability to process the face holistically and induces a more piecemeal processing of separate face parts (Mondloch & Maurer, 2008; Searcy & Bartlett, 1996; Yin, 1969). Experiment 2, therefore, tested participants' ability to shift attention to cued happy and angry faces on the dot-probe task with *inverted* faces. If participants are able to shift attention to the cued expressions, as in Experiment 1, it would indicate that top-down attentional sets for facial expressions can be instantiated by specific facial features (e.g., upturned lips could drive attention to happy faces). If, however, participants cannot shift attention to the cued expression, it would indicate that top-down orienting to facial expressions requires holistic processing.

Method

Participants. Forty-seven participants were recruited via the Australian National University Online sign-up portal. Participants' ages ranged from 18 to 29 years (M = 20.21, SD = 2.35), 46 participants were right-handed and 1 was left-handed, 19 participants were male, 27 were females, and 1 participant did not disclose their gender. Participation took approximately 10 minutes. Participants completed Experiment 3 and then Experiment 2 and were offered 45 minutes of course credit.

Experimental stimuli, apparatus, and procedure. Experiment 2 replicated Experiment 1, with two exceptions: (1) the faces were inverted, and (2) the emotion-neutral (incorrect cue) condition was excluded since it was not essential to test the hypothesis. Furthermore, since participants were also required to complete Experiment 3 with Experiment 2, it was helpful to reduce the trial numbers so that participation time could be kept to 45 minutes to reduce fatigue effects. The following face pairs were used: happy-neutral, angry-neutral, and happy-angry faces. The probe could either be presented in the cued or un-cued location. This experiment consisted of 12 practice trials and 320 experimental trials with 6 rest breaks.

Results and Discussion

One participant's data were excluded due to pressing the wrong keys (100% invalid key press). A further two participants' data were excluded as they did not meet criteria for being Caucasian and one additional participant's data were excluded as the RT constituted an outlier (z-score > 3.29). Therefore, 43 participants' data were included in further analyses. Trials in which participants made an invalid key press (i.e., hit a key that was not "E" or "F") or responded quicker than 100ms or slower than 2.5 standard deviations from their average RT were also excluded. This accounted for an average of 2.2% of participants' data. Accuracy and RTs for the correct trials were then calculated. Mean accuracy on the probe task was 94% (SD = 4.7%) and mean RT was 643.2 (SD = 93.6ms).

Cueing effect. Accuracy was analysed with a 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA. No significant effects were found ($ps \geq .148$). To test whether participants could shift attention to the cued expressions, RT was analysed with a 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA. No significant effects were found ($ps \geq .085$), indicating that participants could not reliably shift attention to the cued expression and that the effects did not significantly differ depending on target facial expression and type of paired expression. Specifically, the cueing effect was clearly non-significant, $F(1, 42) = 1.78$, $p = .190$, $\eta^2 = .041$), with similar RTs on valid trials (M = 641.1ms) compared with invalid trials (M = 645.4ms) (see Figure 3).

Since the results of this experiment failed to reject the null hypothesis, the null hypothesis statistical testing was supplemented with a Bayesian analysis. This revealed that the BF_{10} factors were all <1 for the main effects, two-way interactions and the three-way interaction. This means that there was greater evidence *in favour* of the null hypothesis in this experiment, thereby converging with the results of the hypothesis testing.

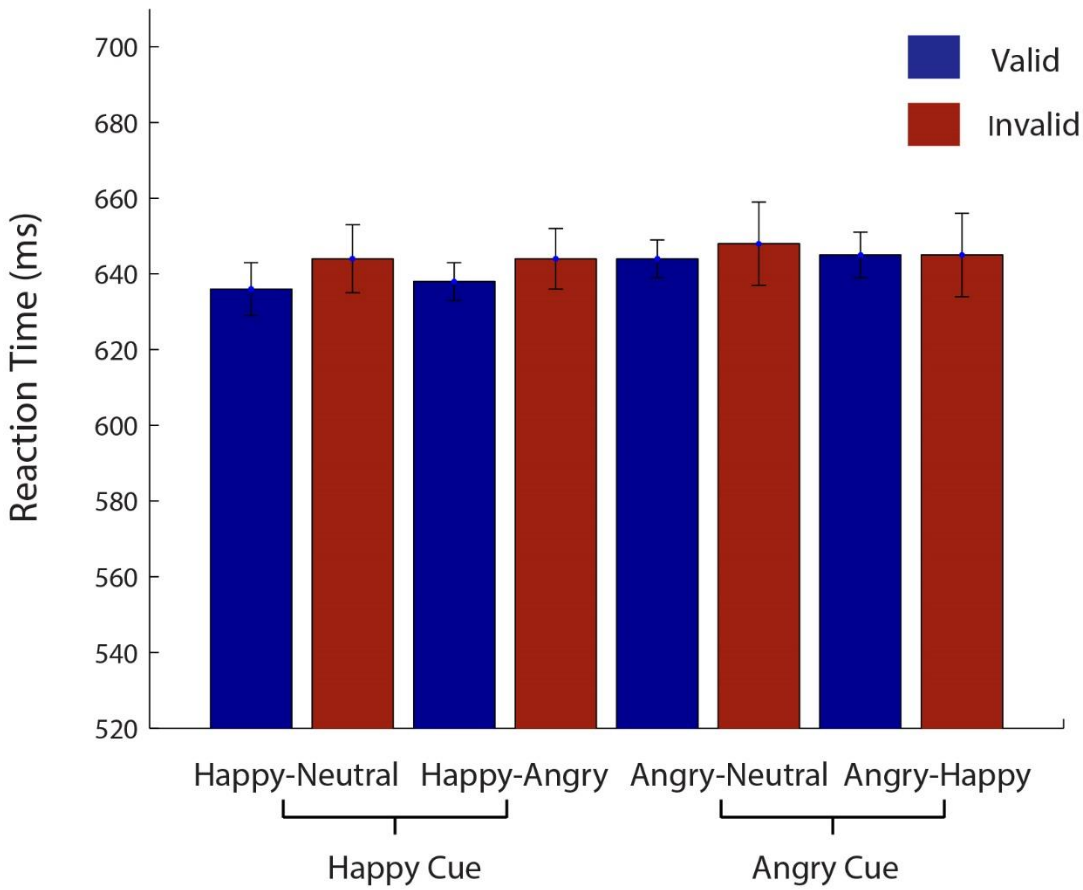


Figure 3. Reaction data for Experiment 2. Within-subjects 95% confidence intervals were calculated using Morey's (2008) correction for within-subject designs.

To summarise, Experiment 2 failed to reveal any evidence that participants were able to use top-down attention to orient to inverted emotional faces. This was evidenced by a non-significant cueing effect. In conjunction with Experiment 1, where there was reliable orienting toward facial expressions, this indicates that top-down attention toward facial expressions is based on perceiving the face holistically rather than searching for individual face parts. Interestingly, the overall RTs from Experiment 2 were faster compared with the RTs in Experiment 1. One possibility is that, because participants could not reliably orient to the inverted face, they tended to disregard the faces and instead relied on bottom-up capture of attention by the onset of the probe to perform the task. This could have led to slightly faster probe detection than in Experiment 2. Critically, however, faster RTs were not found on valid, relative to invalid, trials indicating that participants could not reliably orient to the cued face when the faces were inverted.

Experiment 3

The results of Experiment 1 demonstrated that participants could shift attention to both happy and angry faces, and that the cueing effects did not significantly differ between the two expressions. However, this study did not test participants' baseline bottom-up capture of attention by happy and angry faces. This is an important consideration because participants may have bottom-up biases to happy and/or angry faces. In determining these bottom-up biases, we can then understand how top-down attention may override or compete with bottom-up attention.

The incorrect-cue condition partly measured bottom-up capture of attention, as it tested participants' ability to ignore irrelevant emotional stimuli. However, in this condition, participants were still given a top-down set ("Happy" or "Angry"). To provide a purer measure of bottom-up attention, no top-down cues should be provided. To this end, Experiment 3 utilised a modified dot-probe task of happy-neutral, angry-neutral, and happy-angry paired trials and participants did not receive any instructions of which faces to attend. In addition, the probe was equally likely to follow angry, happy, or neutral faces and so there were no top-down effects regarding expectations of where the probe was most likely to appear. The following experiment, therefore, tested whether participants have an attentional bias toward happy or angry facial expressions.

Method

Participants. The sample from Experiment 2 also completed Experiment 3.

Experimental stimuli, apparatus, and procedure. Each trial consisted of 500ms of blank screen with a fixation cross, then the paired faces were presented for 200ms, and was followed by 300ms of probe presentation. Participants were then presented with a blank screen which remained visible until they made a response. Crucially, however, they were instructed to identify the probe as quickly and accurately as possible as soon as they saw it. As with Experiment 1, paired faces could be happy-neutral, angry-neutral, or happy-angry. The six trial types were: (1) happy-neutral, probe follows happy, (2) happy-neutral, probe follows neutral, (3) angry-neutral, probe follows angry, (4) angry-neutral, probe follows neutral, (5) happy-angry, probe follows happy, and (6) happy-angry, probe follows angry. This task consisted of 12 practice trials and then 120 experimental trials, with two rest breaks. The presentation of the six trial types was randomised throughout the experiment with the restriction that there were 20 trials for each condition. All other stimuli and apparatus details were identical to Experiment 1.

Results and Discussion

As with Experiment 2, one participant's data were excluded due to 100% invalid key presses and a further two participant's data were excluded as they did not meet criteria for being Caucasian. However, the participant's data which constituted an outlier in Experiment 2 was not an outlier in Experiment 3. Therefore, data from 44 participants were included in the analyses of Experiment 3. Trials in which participants made an invalid key press (i.e., hit a key that was not “E” or “F”) or responded quicker than 100ms or slower than 2.5 standard deviations from their average RT were also excluded. This accounted for 2% of participants’ data. Accuracy and RTs for the correct trials were then calculated. Mean accuracy on the probe task was 92.9% (*SD* = 5.1%) and mean RT was 576.2ms (*SD* = 59.7ms).

Accuracy was first assessed across the six trial types. Using a 6 (trial type) repeated-measures ANOVA, no significant differences in accuracy were found, $F(5, 215) = .39$, $p = .855$, $\eta^2 = .009$. To test whether participants’ RT differed across the six types of trials depending on paired facial expression and probe location, a 6 (trial type) repeated-measures ANOVA was conducted. No significant differences were found between the trial types, $F(5, 215) = 1.07$, $p = .377$, $\eta^2 = .024$ (see Figure 4). This indicates that, with an unselected sample, there are no preferences to attending to happy, angry or neutral facial expressions.

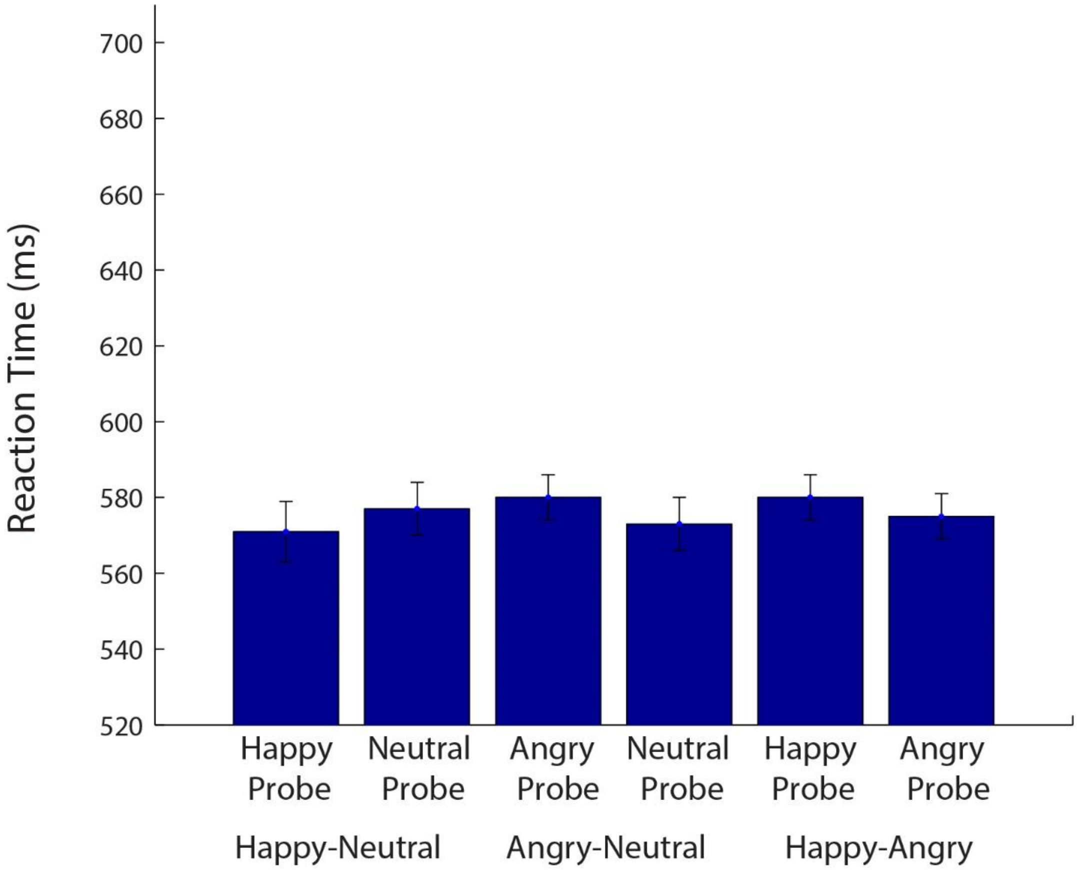


Figure 4. Reaction data for Experiment 3. Within-subjects 95% confidence intervals were calculated using Morey's (2008) correction for within-subject designs.

Once again, since the results of this experiment failed to reject the null hypothesis, the null hypothesis statistical testing was supplemented with Bayesian analysis. This revealed that the BF_{10} for the effect of trial type was <1. This means that there was greater evidence *in favour* of the null hypothesis in this experiment. Therefore, this converges with the results of the hypothesis testing.

In summary, Experiment 3 found no evidence for a bias toward happy, angry, or neutral facial expressions. Interestingly, the overall mean RTs were shorter in Experiment 3, compared with the RTs from Experiment 1 and Experiment 2. This indicates that not having a top-down cue for an emotional expression and, instead, relying on bottom-up attentional capture by the probe, resulted in faster RTs to the probe. Crucially, however, the results of Experiment 3 reveal that, in the absence of a top-down set, participants did not have a bottom-up bias to emotional faces.

Experiment 4

Experiment 1 did not support selection history as a mechanism of attention to specific facial expressions. Experiment 4 was conducted to examine the effect of selection history more fully. Specifically, it is possible that selection history effects require more than one repeated trial to result in increased cueing effects. For this reason, Experiment 4 compared a mixed condition, in which the cued face (happy or angry) changed randomly throughout the trial block, with a blocked condition in which participants attended to the same facial expression throughout a block of trials. If cueing effects are larger in the blocked condition compared with the mixed condition, it would indicate that selection history increases participants' ability to rapidly shift attention to emotional faces. However, if the cueing effect does not differ between the blocked and mixed conditions, this would lend further support to the conclusion that selection history is not a major factor in guiding attention to emotional faces.

Method

Participants. Forty-six participants were recruited via the Australian National University online sign-up portal in exchange for course credit. Participants' ages ranged from 18 to 24 years (*M* = 19.76, *SD* = 1.59), 39 participants were right-handed, 6 were left-handed, and 1 identified as ambidextrous, 26 participants were females, 19 were male, and 1 did not disclose their gender. Participation took approximately 30 minutes.

Experimental stimuli, apparatus, and procedure. The stimulus presentation parameters were identical to Experiment 1. However, this experiment consisted of three tasks, which were counterbalanced across participants:

1. Happy block: Participants were instructed to shift their attention toward the happy facial expression. Trials consisted of happy-neutral and happy-angry face pairs. This block consisted of 12 practice trials, and then 160 experimental trials with 7 rest breaks.
2. Angry block: Participants were instructed to shift their attention toward the angry facial expression. Trials consisted of angry-neutral and angry-happy face pairs. This block consisted of 12 practice trials, and then 160 experimental trials with 7 rest breaks.
3. Mixed block: Happy and angry cue trials could randomly change each trial. Face pairs could be happy-neutral, angry-neutral, and happy-angry. This block consisted of 12 practice trials and then 320 experimental trials with 7 rest breaks.

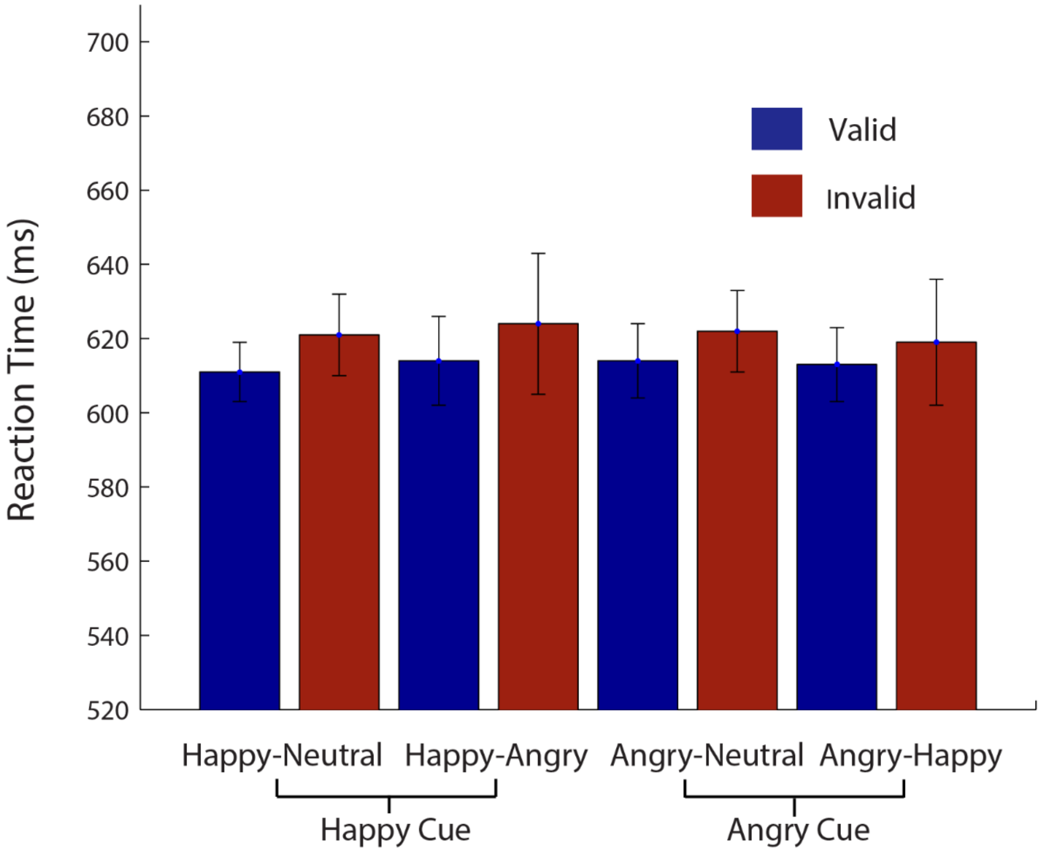
Trials types were randomised throughout the experiment with the constraint that the cued face was predictive of the probe location on 75% of trials. An equal number of cued happy and angry trials were included and an equal number of angry-neutral, happy-neutral, and angry-happy face pair trials were included.

Results and Discussion

Data exclusions were as follows: three participants' data as they did not meet criteria for being Caucasian, two participants' data for chance accuracy, one participant's data for not having normal or corrected-to-normal vision, and four participants' data for outlier RTs (z score > 3.29). Therefore, 36 participants' data were included in the study. Next, 2.2% of data were excluded for invalid key presses and RTs that were quicker than 100ms or slower than 2.5 *SD* from each participant's mean RT. Accuracy and RTs for the correct trials were then calculated. Mean accuracy on the probe task was 91.5% (*SD* = 5.1%) and mean RT was 600.4 ms (*SD* = 57.2 ms).

Cueing effect. Accuracy was analysed with a 2 (condition: mixed or blocked) x 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA. A significant effect of condition was found, $F(1, 35) = 23.10$, $p < .001$, $\eta^2 = .398$, with higher accuracy in the mixed condition ($M = 93.1\%$) compared with the blocked condition ($M = 89.7\%$). No other significant effects were found ($ps \geq .064$).

To test whether blocking the top-down cue increased the cueing effect, a 2 (condition: mixed or blocked) x 2 (target face: happy or angry) x 2 (distractor face: neutral or emotional) x 2 (cue: valid or invalid) repeated-measures ANOVA on RT was conducted. A significant effect was found for cue validity, $F(1, 35) = 6.96$, $p = .012$, $\eta^2 = .166$, with faster RTs on valid ($M = 597.3$ms) compared with invalid trials ($M = 603.6$ms). Condition was also significant, $F(1, 35) = 14.23$, $p = .001$, $\eta^2 = .289$, with faster RTs in the blocked condition ($M = 583.5$ms) compared with the mixed condition ($M = 617.4$ms). However, although participants were generally faster in the blocked condition, the interaction between condition and cue validity was not significant, $F(1, 35) = .88$, $p = .354$, $\eta^2 = .025$, indicating that the cueing effect did not significantly increase when the target face was blocked (see Figure 5). Therefore, no evidence for selection history was found. No other significant effects were found ($ps. \geq .191$)[5]. Convergent evidence arose from the Bayesian analysis, which confirmed evidence in favour of the null hypothesis for the interaction between condition and cue validity (BF<1).



Reaction Time (ms)
700
680
660
640
620
600
580
560
540
520
Valid
Invalid
Happy-Neutral
Happy-Angry
Angry-Neutral
Angry-Happy
Happy Cue
Angry Cue

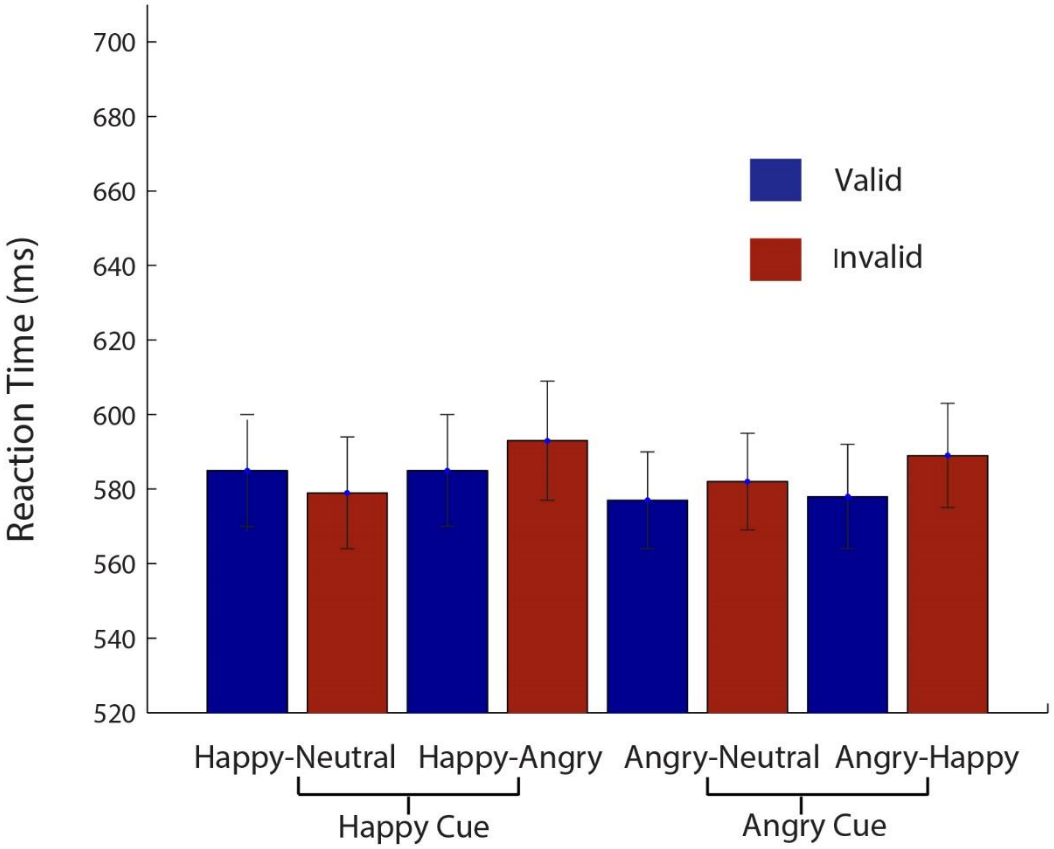


Figure 5. Reaction data for Experiment 4 for each cued face and face-pair separately. Mixed condition is presented TOP and blocked condition is presented BOTTOM. Within-subjects 95% confidence intervals were calculated using Morey's (2008) correction for within-subject designs.

In summary, Experiment 4 compared conditions in which participants were instructed to attend to one facial expression in a block of trials (blocked condition) compared with when the cued face randomly changed across trials (mixed condition). An overall speed-accuracy trade-off effect was revealed, with faster RTs but reduced accuracy for the blocked condition. Critically, however, there was a reliable cueing effect, with faster RTs on valid versus invalid trials, indicative of the fact that participants shifted their attention to the cued face. This cueing effect was evident in both block conditions and hence uncontaminated by the speed-accuracy trade-off. Critically, no effect of selection history was found as the cueing effect did not significantly differ between the mixed and blocked conditions. That is, repeated practice of attending to the same facial expression did not improve participants' ability to attend to the cued face compared with the opposite location.

Gender effect. Although not directly relevant to the hypotheses of the current study, data from each of the four experiments were also analysed to test if the gender of the faces employed and the gender of the participants affected results (e.g., Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Hess, Blairy, & Kleck, 1997; Wells, Gillespie, & Rotshtein, 2016). No consistent results were found across experiments. For example, Experiment 1 found slightly faster RTs to the probe on trials with male, happy target faces paired with a neutral face compared with an angry-neutral face-pair (p = .004). In addition, on happy-neutral and angry-neutral face-pair trials, female participants had a larger cue validity effect compared with male participants (p = .05). However, there were only 14 male participants, which is a relatively small sample size and, therefore, these results should be interpreted with caution. No other significant main effects or interactions were found for face gender ($ps \geq$ .219) or participant gender ($ps \geq$ .124). Next, Experiment 2 found that female participants, but not male participants, displayed significantly (p = .031) faster RTs on happy-target trials (M = 636.9ms) compared with angry-target trials (M = 647ms). No other significant main or interactive effects were found for face gender ($ps \geq$ .160) or participant gender ($ps \geq$ .174). Experiment 3 found no significant main or interactive effects for face gender ($p \geq$. 533) or participant gender ($p \geq$. 574). Similarly Experiment 4 found no significant main or interactive effects of face gender (p = .346) or participant gender (p = .278). Altogether, the inconsistency in the reliability of these results across the experiments suggest that the gender of the faces or participants were not important factors in this study.

General Discussion

Across four experiments, the current study used a modified dot-probe design to test the relative contributions of top-down attention, bottom-up attention, and selection history mechanisms for shifting attention to emotional faces. The major finding of the current study was that participants could shift their attention in a top-down manner toward both angry and happy facial expressions, as evidenced by significant cueing effects in response to top-down cues. The current study found that an unselected sample of participants did not have a bias toward either happy, angry, or neutral facial expressions (Experiment 3). Instead, when given a cue to attend to happy or angry faces, participants were able to rapidly deploy attention to those cued expressions using top-down attention (Experiment 1). Experiment 2 indicated that holistic rather than feature-based processing of the face was implicated in this top-down set, as the cueing effect was eliminated when the faces were inverted. Furthermore, the evidence from both Experiments 1 and 4 implies that this was driven by top-down, rather than selection history effects, as target repetition did not benefit attentional orienting.

These findings challenge the prevailing notion that attentional orienting to facial expressions in driven by bottom-up factors. Instead, here, top-down processes were clearly the dominant contributing factor. While we did not find any evidence for bottom-up processes, this does not preclude the possibility that they can, at times, contribute to attentional orienting to faces, in certain contexts or perhaps for certain individuals (such as those with higher levels of social anxiety). What it does mean, however, is that top-down attentional processes play a key role in how attention is applied to human facial expressions. This belies notions of “fear-relevant” modules in the brain (e.g. Öhman & Mineka, 2001) that process threatening facial expressions in a way that is impervious to top-down attentional processes.

An important methodological strength of the current experiments was the inclusion of the happy-angry face pairs. The fact that reliable cueing occurred on those trials rules out alternative, non-top-down explanations for the orienting, such as bottom-up capture by emotional faces. That is, in theory, bottom-up capture by emotional faces could have led to cueing effects for the angry-neutral and happy-neutral pairs. However, this possibility is refuted by the fact that participants were also able to orient their attention to either the happy or angry face when it was paired with an emotional face distractor. A bias toward emotional faces in general would not have produced reliable attentional orienting effects for such trials. In addition, if only happy-neutral and angry-neutral trials had been included in the study, participants could have developed a top-down set for emotional faces, or selection history could have emerged producing a bias toward any emotional face, since the probe was more likely to appear behind the emotional face compared with the neutral face. However, reliable cueing effects were found on happy-angry trials, irrespective of whether the happy or angry face was the target. This indicates that participants were flexibly able to switch, on a trial-by-trial basis, between orienting to happy and angry faces. Further evidence for this is the fact that participants were reliably faster to respond to a validly cued probe on happy-neutral and angry-neutral trials compared with when the probe followed an incorrectly cued emotional face (e.g., a happy cue preceded an angry-neutral face pair). Thus, the content of the top-down set had to include at a *minimum* the valence of the particular expression (e.g. positive / negative), if not the specific expression itself (happy / angry). Future research could include additional expressions (e.g. sadness) to distinguish between valence and specific-expression-based content of the top-down set.

Previous research exploring top-down attentional orienting has largely employed basic visual stimuli, such as colour, shape, and motion cues, (for a review, see Folk & Remington, 2010). However, Wyble et al. (2013) demonstrated contingent capture effects for superordinate-level visual stimuli, such as sports equipment, food, and animals. The results of the current study indicate that, in addition to these types of stimuli, individuals can orient their attention in a top-down manner toward different facial expressions (or at least valences), which differ quite subtly in their low-level visual properties. Furthermore, the current study found that when the faces were inverted, participants were no longer reliably able to orient to the cued expressions. Since inversion disrupts the ability to perceive the holistic qualities of faces (Mondloch & Maurer, 2008; Searcy & Bartlett, 1996; Yin, 1969), these findings suggest that participants relied on a holistic top-down set of an emotional face to be able to rapidly shift attention toward it. Surprisingly, however, faster overall responses were found in Experiment 2 in which the faces were inverted, compared with Experiment 1, which employed upright faces. One possibility is that, because participants could not reliably orient to the cued inverted face, they relied on bottom-up capture of attention by the probe instead. This is consistent with the rapid responses that were found in Experiment 3, when no top-down cue was provided. This reveals one potential limitation of the dot-probe task employed in this study; faster RTs may be found when participants were watching out for the probe compared with when orienting to the cued faces. One method of overcoming this issue would be to have participants answer a question about the target itself (rather than a probe that appeared in the locus of the target). For example, a common design with more basic stimuli has been a singleton search with one target amongst distractors. Typically, the target is defined by its differing shape (e.g., diamond amongst circles) or colour (red circle amongst green circles) and participants are asked to respond to the orientation of a line segment presented inside the target shape (Theeuwes et al., 2006). Therefore, a modification of the current study could be to respond to the gender of the target face.

Selection history appeared to play no role in facilitating attentional orienting to facial expressions in this study. This was supported both by trial-by-trial analyses (Experiment 1) and keeping the cued expression constant across a block of trials (Experiment 4). This contrasts with some previous research which claimed that spatial orienting toward visual stimuli was driven by selection history and not top-down attention (Theeuwes et al., 2006; Theeuwes, 2013). For example, Theeuwes et al. (2006) cued on each trial (with 80% validity) a target, which could either be a shape or colour singleton. No cueing effects were found, indicating that foreknowledge (i.e., top-down attention) did not facilitate attentional orienting. By contrast, when a symbol cue was used, in which the cue was identical to the target, cueing effects were revealed (even when the cue was not predictive of the target). This research demonstrates that top-down attention did not guide attention to featural singletons, as instead, improved performance was driven by selection history (labelled as "bottom-up priming" in this study). Due to concerns that employing a singleton pop-out target made the task too easy, Theeuwes and Van der Burg (2011) conducted a series of similar experiments in which there were two pop-out stimuli (red or green colour singletons) presented alongside five grey distractors. These researchers found that when a verbal cue was used, participants were unable to inhibit attention to an irrelevant coloured distractor, whereas when a symbol cue was used, participants were able to more reliably attend to the target and ignore the distractor. This is likely because the symbol cue, unlike the verbal cue, primed the features of the target, resulting in cue-target priming (which can be thought of as a type of selection history). Overall, the results of Theeuwes and Van der Burg (2011) and Theeuwes et al. (2006) indicate that, even for difficult displays when there are two featural singletons competing for attention, selection history and not top-down attention drives attentional orienting to features.

However, Belopolsky and Awh (2016) found top-down guidance of attention for visually complex arrays in which pop-out was not present. That is, these researchers used a similar design to Theeuwes et al. (2006) in which participants were presented with a verbal colour cue and then viewed a six-item display and were asked to respond to the orientation of the line segment contained in the target. When a pop-out design was used, in which the target was a separate colour to the distractors, selection history effects were revealed but top-down knowledge of the target did not reliably improve performance. By contrast, if the distractors each had a different colour in the display, and so pop-out effects were eliminated, both selection history and top-down attention had separate contributions to target detection. Other research has confirmed the role of top-down attention to spatial attentional orienting using basic stimuli (Becker, 2018; Becker, Lewis, & Axtens, 2017).

The absence of a selection history effect in the present study indicates that we may have identified some boundary conditions for selection history. This, in turn, has the potential to provide important information about the nature of selection history. There are three key differences between the present study and the methods that have been used to date to examine selection history. It is possible that one of these factors prevented selection history effects from emerging, or a combination of two or all three of the factors. Firstly, photographs of faces are visually more complex in a number of ways than simple shape and colour cues (e.g., green circle). This raises the possibility that selection history effects are only present for basic stimuli such as simple shapes and colours. If so, then this would be important to know, because it would inform us that selection history effects are likely to be of little consequence in real-world vision, and therefore should not be a focus of laboratory research. Secondly, in the current study, the same expression either repeated or switched across trials. However, this expression could be from different models (i.e., different individual faces). Thus, selection history effects may be limited to repetition of identical exemplars, and not generalise to category-level effects. This would reflect a dissociation between selection history and top-down attention, which can operate at category level beyond individual exemplars (Goodhew et al., 2014; Most, 2013; Wyble et al, 2013). A straightforward way of testing this explanation and distinguishing it from the first would be to determine whether selection history effects emerge for faces when the same face is presented across trials. Thirdly, selection history may be intrinsically tied to the nature of the task. In standard selection history paradigms participants make a response about the stimulus that is repeated (e.g., indicating the orientation of a line within a red target on two consecutive trials). However, in the present study, the probe to which participants responded was a separate stimulus from the stimuli that they had used to guide their attention (i.e., the faces). It is possible that selection history effects only apply to the actual stimulus that is selected. If so, then they should be observed when participants make a response about the face itself, rather than the stimulus that appears after it. Disentangling these possibilities promises to shed new light on selection history and its function.

Conclusions

The results of the current study are novel in demonstrating the role of top-down attention in orienting toward facial expressions, challenging existing ideas about attentional orienting to facial expressions being driven by bottom-up processes. Specifically, participants could flexibly shift their attention toward both happy and angry faces, even in the presence of competing emotional information. This effect relied on holistic processing rather than feature-based processing of the faces. Selection history did not affect attentional orienting to faces. This means that we discovered boundary conditions for selection history, highlighting exciting avenues for future research to improve our understanding of the function of selection history. Altogether, the implications of these results are that even when it comes to emotionally-evocative facial expressions, individuals are not at the mercy of pre-determined bottom-up salience, but instead, can use their top-down attention in flexible and dynamic ways to orient their attention to goal-relevant stimuli.

Notes

1. This research was supported by an Australian Research Council (ARC) Future Fellowship (FT170100021) awarded to S.C.G.
2. Since designing the study, it has come to our attention that G*Power does not allow for the computation of power for designs with more than one repeated-measures factor, as was present here. When we specify eight measurements G*Power assumes that these all reflect levels of one variable (8x1), rather than a 2x2x2 factorial design. For future research we plan to use the superior newly available calculators which permit these sorts of common experimental designs, in addition to permitting for correction for publication bias (Anderson, Kelley, & Maxwell, 2017). However, since G*Power was used, its results are reported here.
3. In the raw data file that is publicly available in OSF, the columns for summary overall accuracy and RT per participant were compiled from all correct trials for RT and all trials for overall accuracy (on which a valid keypress was made). Note that these differ slightly from the average overall accuracy and RT values provided in the results section here, which were calculated by taking the mean score of all of the variables. (The values differ slightly because different participants and different conditions contain different numbers of trials, e.g., more trials in valid than invalid conditions, if a participant is more accurate then more trials feed into the first accuracy measure, whereas the second assumes constant number of trials across participants). Both types of aggregate scores provide useful albeit slightly different pieces of information, and so we have provided both to readers.
4. Surprisingly though, a significant four-way interaction was found between target expression, paired face, validity, and repetition, $F(1, 42) = 4.37$, $p = .043$, $\eta^2 = .094$. To further analyse this effect, an ANOVA was conducted for the happy and angry

target faces separately. This found that, for the angry faces, the interaction between paired face, validity, and repetition were not significant, $F(1, 42) = 2.04$, $p = .161$, $\eta^2 = .046$. This indicates that, when participants were orienting to angry faces (when paired with either a neutral or happy face), there was no effect of selection history. For the happy target face, the interaction between the paired face, validity and repetition was also not significant, $F(1, 42) = 3.25$, $p = .079$, $\eta^2 = .072$. These results indicate that no clear evidence was found for selection history.

5. Note that additional preliminary analyses were conducted for sequence effects (whether participants completed the mixed or blocked condition first). An interaction was found between condition and sequence effects (with large reductions in RT found in the mixed condition when it was performed second in sequence, compared with when it was performed first). However, these effects did not interact with validity (*ps* $\geq .229$).

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Chapter Six. The Effect of Social Anxiety on Top-Down Attentional Orienting to Emotional Faces

Chapter Overview

Chapter Five demonstrated that attentional orienting to emotional faces can be driven by top-down attention, finding no evidence for bottom-up capture to threat for an unselected sample and no evidence for selection history. Chapter Six extends on the research of Chapter Five and tests whether top-down orienting of attention to emotional faces is impaired for individuals with high levels of social anxiety relative to those with lower levels of social anxiety. Two competing hypotheses are tested; hypothesis one is that socially anxious individuals could suffer from a general deficit in attentional control, resulting in difficulty orienting attention in response to all top-down cues. Hypothesis two considers that socially anxious individuals could have a more selective deficit, such that difficulty orienting to a cued face would only be observed in the presence of competing threatening information.

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Author Contributions

- **Delchau** proposed the project.
- **Delchau** designed the experiment with contributions from Goodhew, Christensen, and Lipp.
- **Delchau** coded the computer task.
- **Delchau** collected the data.
- **Delchau** analyzed the data, with advice from Goodhew.

- **Delchau** and all other authors contributed to discussions surrounding interpretation of the data.
- **Delchau** produced the tables and figures.
- **Delchau** wrote the manuscript, with editing provided by Goodhew, Christensen, and Lipp.

The effect of social anxiety on top-down attentional orienting to emotional faces

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Running head: Social anxiety and orienting to emotional faces

Abstract

One of the fundamental factors maintaining social anxiety is biased attention toward threatening facial expressions. Typically, this bias has been conceptualised as driven by an overactive bottom-up attentional system; however, this potentially overlooks the role of top-down attention in being able to modulate this bottom-up bias. Here, the role of top-down mechanisms in directing attention toward emotional faces was assessed with a modified dot-probe task, in which participants were given a top-down cue ("Happy" or "Angry") to attend to a happy or angry face on each trial, and the cued face was either presented with a face of the other emotion (angry, happy) or a neutral face. This study (*N* = 110) found that social anxiety was not associated with differences in shifting attention toward cued angry faces. However, participants with higher levels of social anxiety were selectively impaired in attentional shifting toward a cued happy face when it was paired with an angry face, but not when paired with a neutral face. The results indicate that top-down attention can be used to orient attention to emotional faces, but that higher levels of social anxiety are associated with selective deficits in top-down control of attention in the presence of threat.

Keywords: selective attention, spatial attention, social anxiety, dot-probe, threat bias.

The effect of social anxiety on top-down attentional orienting to emotional faces

In life, we are bombarded with visual information, only a small amount of which we can process. A key function of the attentional system is to filter information, separating relevant input from input that can be ignored. In the literature, an attentional bias for threatening facial expressions has been found among socially anxious individuals (Grafton & MacLeod, 2016; Lin, Hofmann, Qian, Kind, & Yu, 2016; Mogg & Bradley, 2002; Mogg, Philippot, & Bradley, 2004; Pishyar, Harris, & Menzies, 2004; Schofield, Johnson, Inhoff, & Coles, 2012). For instance, Lin and colleagues (2016) found that, when giving a speech, participants with high levels of social anxiety spent longer looking at audience members displaying negative facial expressions and less time looking at audience members displaying positive facial expressions than did participants with low levels of social anxiety. Research indicates that attentional bias towards threat is an important factor in the maintenance, and perhaps even causation, of anxiety (MacLeod & Mathews, 2012; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Rapee & Heimberg, 1997; Van Bockstaele et al., 2014). While it is true that some studies have not found evidence for a threat bias associated with social anxiety, these tend to be the exception rather than the rule, and there are typically methodological differences in these studies (e.g., long stimulus presentation times of 1000ms) that could account for not observing the bias in these cases (Gotlib et al., 2004, Bradley et al., 1997; Pineles & Mineka, 2005). Moreover, at times, individuals with high levels of social anxiety also appear to have a bias *away* from threat, though this has been associated with methodological differences in the type of paired image (e.g., inverted faces or household items) (Boal, Christensen, & Goodhew, 2018; Chen, Ehlers. Clark, & Mansell, 2002). Both enhanced engagement with threat and avoidance of threat are conceptualised as reflecting the temporal dynamics of the atypical attentional processes that characterise anxiety (Cisler & Koster, 2010; Zvielli, Bernstein, & Koster, 2014). Altogether, the literature indicates that individuals with high social anxiety have atypical attentional processing patterns in the presence of threatening information, which is most often observed as a bias toward threat. To develop treatments that may break the reinforcing loop between this threat bias and increasing levels of social anxiety, it is essential to understand the underlying attentional processes driving this threat bias. Therefore, the present study applied key theoretical concepts from the attention literature to understand the nature of the threat bias in social anxiety; namely, whether biased attention is associated with top-down attention, bottom-up attention, and/or selection history. (Note that when we use the term *social anxiety* throughout, we are referring to a construct assumed to exist as a dimension on which individuals in the population vary and for which high levels may, but do not necessarily invoke a diagnostic category).

A core distinction that resonates throughout the attention literature is that between top-down and bottom-up attention (e.g., Corbetta & Shulman, 2002). Top-down attention refers to the voluntary allocation of attention toward particular objects, features, or spatial locations based on one's current goals (e.g., searching for a friend's red hat in a crowd). In contrast, bottom-up attention is an involuntary, rapid, and inflexible process that selects visual information based on the salience of stimulus features (e.g., a red object amongst green distractors). In addition, a third attentional mechanism has recently been recognised; that of selection history (Awh, Belopolsky, & Theeuwes, 2012). Selection history is attentional capture due to past selection or past reward history of a visual stimulus, even if it no longer matches an individual's top-down goal. Selection history is considered distinct from either top-down or bottom-up processes (Awh et al., 2012). Below, we review evidence for the threat bias associated with social anxiety, discussing the possibility that it is linked with impaired top-down attentional control.

At present, the processes mediating biased attention toward threat remain relatively unknown. The normative attention literature informs us that top-down attention is a powerful mechanism that can override the attentional capture by salient stimuli. For example, while a unique-onset stimulus appearing in a display typically captures attention via bottom-up mechanisms, this capture can be overridden if an individual is instead searching for a differently-coloured target, as the onset does not match their top-down attentional goal (Folk, Remington, & Johnston, 1992). The influence of top-down attention over attentional orienting has also been demonstrated for emotional faces (Barratt & Bundesen, 2012). Barratt and Bundesen (2012) found that attentional capture by task-irrelevant negative faces depended on whether the task-relevant stimulus was a face or not, which presumably led to different top-down attentional goals. More specifically, in one experiment, participants were instructed to respond to the identity of a central schematic face surrounded by distractor faces. Reaction times (RTs) were slower for positive face targets when they were flanked by negative faces compared with positive or neutral faces, indicating involuntary capture of attention by negative faces. However, when the central target was a letter instead of a face, there was no such RT slowing, indicating that participants' attention was no longer captured by the negative face distractors. This suggests that spatial attentional capture by negative faces can be modulated by top-down attention (i.e., whether or not one was looking for a face target).

The above-reviewed empirical examples suggest that bottom-up attentional capture by threatening or otherwise-salient stimuli can be overridden by top-down control of attention. However, there are also theoretical reasons to believe that voluntary attentional control may be impaired among individuals with anxiety. For example, Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007) posits that anxious individuals have an imbalance between top-down and bottom-up attention, with increased influences from bottom-up capture of attention and poorer top-down control. According to this model, as a result of reduced attentional control, anxious individuals are more likely to have difficulty inhibiting attention toward task-irrelevant stimuli, shifting attention between tasks, as well as updating information (e.g., reading and operation spans), particularly in stressful situations.

A similar account has been proposed by Bishop, Jenkins, and Lawrence (2007), who manipulated perceptual load to examine the role of top-down attention in the processing of threatening stimuli for individuals with varying levels of state and trait anxiety. That is, compared with high perceptual load conditions, under low perceptual load, participants have a greater availability of spare attentional resources and so top-down attention is required to regulate attention and prevent it from being directed to salient, but task-irrelevant stimuli such as threat. Bishop et al. (2007) presented participants with a string of six letters superimposed on the image of a face, which either had a fearful or neutral expression. Participants' task was to identify whether the letter string contained an "X" or an "N". The faces were therefore always task-irrelevant. High perceptual load was induced by presenting the target X/N amongst 5 nontarget letters (H, K, M, W, Z), whereas low perceptual load was induced by presenting a homogenous string of six Xs or Ns. Bishop et al. (2007) found that under low perceptual load, anxious participants exhibited a pattern consistent with enhanced allocation of attention to the task-irrelevant threatening stimuli and reduced top-down control. More specifically, under conditions of low perceptual load, state anxious participants displayed heightened Blood Oxygenation Level Dependent (BOLD) responses in the amygdala and superior temporal sulcus triggered by task-irrelevant fearful facial expressions, and trait anxious participants displayed reduced BOLD responses in prefrontal regions associated with top-down attentional allocation of resources. Bishop et al. (2007) concluded that elevated trait anxiety is associated with poorer recruitment of top-down attention, which is necessary for ignoring the distracting faces. More recent research has also found that anxiety is associated with impoverished recruitment of frontal cortical regions implicated in attentional control on tasks with non-emotional stimuli (Bishop, 2009).

In sum, previous research converges on the conclusion that trait anxiety is associated with deficits in top-down control, thus resulting in bottom-up biases operating unchecked. However, given the focus of previous research, there is still an important gap in the literature. That is, Bishop et al. (2007) employed centrally-presented faces, which means that attentional shifts through space, which are central to models of biased attention, were not necessary in these tasks. Furthermore, participants' ability to use goal-directed attention to orient attention to emotional faces was not directly measured. Finally, Bishop and colleagues' (2007) population of interest was state and trait anxiety, rather than social anxiety. While there is, of course, overlap between trait anxiety and social anxiety, they are theoretically distinct. Therefore, the aim of the current study was to investigate the manner in which individuals who are higher in social anxiety differ in their capacity to exert attentional control in the context of emotional stimuli, as compared to individuals lower in social anxiety. This was done in a context where spatial attentional shifts were directly manipulated.

We also sought to distinguish between two alternative accounts. One is that, relative to those lower in social anxiety, socially anxious individuals could suffer from a general deficit in attentional control, which would be revealed as an impairment in orienting attention in response to all top-down cues. The alternative is that socially anxious individuals could have a more selective deficit, such that an impairment in using top-down attention is revealed only in the presence of competing threatening information. In other words, top-down attentional deficits would manifest only when the bottom-up signal was particularly potent.

To test these accounts, the current study employed a modified dot-probe paradigm with emotional photographic faces. In a standard dot-probe task, participants initially fixate on a central fixation cross. A pair of images of different valences is then presented, usually one to the left and one to the right of fixation. These stimuli then offset after a short period of time (e.g., 500ms) and a target probe (e.g., the letter E or F) replaces one of the images and participants are instructed to respond to its identity (or detect its presence or location in some cases) as quickly and accurately as possible. Faster responses to the probe when it replaces a threatening image (e.g., an angry facial expression) compared with a neutral image (e.g., neutral facial expression) are considered to reflect an attentional bias toward threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Macleod, Mathews, & Tata, 1986). The modification of the standard dot-probe paradigm employed here was to add explicit top-down cues at the beginning of each trial, which indicated to which face participants should attend. By adding these cues, participants were given a top-down goal on each trial to attend to a particular facial expression. This, therefore, tested participants' ability to exert top-down attentional control and shift attention to the cued expression and inhibit attentional capture by the distractor face. The cue was valid (i.e., predicted the location of the subsequent target) on most, but not all of the trials. Participants' ability to use the cue is measured by the difference in RT for the valid compared with the invalid trials (i.e., a cueing effect). No difference in RT between these trials (i.e., no cueing effect) would suggest that no attentional shift occurred in response to the cues, whereas faster responses on valid compared with invalid trials (i.e., a cueing effect) indicates that participants shifted their attention in response to the cue.

The dot-probe paradigm was employed because, rather than using a single centrally-presented image (e.g., as per the flanker task), the dot-probe paradigm entails the presentation of two competing images. This more accurately gauges the theoretical process of interest: *shifts* of attention across space. This also has ecological validity as, for example, when an individual with social anxiety gives a speech, he or she may make attentional shifts to different audience members and attend to those with bored or critical expressions rather than those with encouraging expressions.

An important issue when measuring top-down attention is that it can be confounded by effects of selection history. Selection history refers to instances where visual attention is captured based on one's past selection and reward history (Awh et al., 2012). In an early demonstration of selection history, Maljkovic and Nakayama (1994) conducted a pop-out visual search task in which participants made speeded responses to a target defined by colour or spatial frequency cues. Faster RTs were found when the same target repeated across two trials, compared with when it switched. In fact, this speeding of responses occurred even when participants knew with 100% certainty the identity of the target on the upcoming trial, indicating that selection history can guide attention even when it differs from one's current goal (Belopolsky & Awh, 2016; Theeuwes, Reimann, & Mortier, 2006; Theeuwes & Van der Burg, 2013). Since some researchers have theorised that selection history may independently contribute to threat biases (Peschard & Philippot, 2016), it was also studied in the current experiment by examining participants' ability to orient to the cued facial expression separately for trials in which the target repeated from the previous trial, compared with when it switched.

To summarise, the current study measured social anxiety, and quantified top-down control by measuring cueing effects for happy or angry face cues provided on each trial that directed participants to attend to particular facial expressions. Previous theory and research indicate that anxious individuals have deficits in top-down control, and this can occur in the presence of threatening stimuli as well as non-emotional stimuli. Therefore, two competing hypotheses were tested: (1) participants with higher levels of social anxiety will demonstrate reduced cueing effects when orienting to a happy face paired with a distracting angry face, but will have similar cueing effects in other conditions, or (2) participants with higher levels of social anxiety will demonstrate reduced cueing effects in all conditions, regardless of the presence or absence of threat.

Method

Participants

One-hundred and ten participants were recruited via the Australian National University online sign-up portal and online Australian National University advertising portals. Ethical approval was provided by the Australian National University Human Research Ethics Committee (protocol number: 2014/534). Participants provided written, informed consent. The sample size was determined based on GPower calculations[2]; using the ANOVA function (repeated-measures, between-factors, a priori) with power of 0.9 and an effect size *f* of 0.25 (medium effect). This calculation yielded a recommended sample size of 98 (note that, after participant exclusions, the sample size of the current study was 99 participants). Restrictions were that participants were Caucasian (to match the ethnicity of the face stimuli), aged 18-30 years (to ensure the sample consisted only of young adults, given age-related changes in vision and cognition that may affect task performance), with normal or corrected-to-normal vision. Participants' ages ranged from 18 to 30 years (M = 19.88, SD = 2.61), 4 participants were left-handed, and 34 were males and 76 were females. Participants were offered one hour of course credit or $15 (AUD).

Experimental Stimuli and Apparatus

This experiment was conducted in a dimly lit room. Stimuli were presented on a liquid crystal display monitor running at a 60Hz refresh rate. Viewing distance was set with a chinrest at 44cm. Stimuli were programmed in Matlab using the Psychophysics Toolbox (Brainard, 1997). The background was set to black. On each trial, the word cue could be

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[2] We note that GPower does not provide a direct computation for a 2x2x2 factorial repeated-measures ANOVA with a continuous between-subjects predictor. Instead, we used this function as the closest approximation to the current study's design.

"Happy" or "Angry", which was presented in white, size 18 Helvetica font. Similarly, the probe employed on each trial was either an "E" of "F" and was presented in white, size 18 Helvetica font.

Images of faces were taken from the NimStim database (Tottenham et al., 2009). These consisted of Caucasian faces posing with closed-mouth neutral, happy, and angry expressions. Closed-mouth expressions were chosen to eliminate bottom-up attentional capture by teeth (Horstmann, Lipp, & Becker, 2012). Caucasian images were employed to control for the cross-race effect (for a review, see Young, Hugenberg, Bernstein, & Sacco, 2012), as other-race faces can be processed differently to faces of one's own race. Further exclusions were made due to the incorrect size of one of the images (model 1), confounding facial hair (model 31), and not having a closed-mouth happy face image (model 27). Therefore 22 models (7 females and 15 males) were included, each with three associated images of happy, neutral, and angry expressions. During the experiment, each image subtended approximately 9.4° x 12.1° of visual angle, with a gap of 9.4° of visual angle between the two presented images.

Questionnaires

Participants also completed two questionnaires to measure psychopathology. Firstly, to assess social anxiety, the self-report version of the Liebowitz Social Anxiety Scale (LSAS; Liebowitz, 1987) was employed. This 24-item scale assesses fear and avoidance of social situations. Ratings are made on two 4-point Likert-type scales, with fear rated from 0 ("none") to 3 ("severe") and avoidance rated from 0 ("never, 0%") to 3 ("usually, 68%-100%"). A total score can be calculated by summing scores from both the fear and avoidance scales (maximum = 144). This measure was selected for its good psychometric properties (Baker, Heinrichs, Kim, & Hofmann, 2002; Fresco et al., 2001; Levin, Marom, Gur, Wechter, & Hermesh, 2002; Oakman, Van Ameringen, Mancini, & Farvolden, 2003; Rytwinski et al., 2009), brevity and ease of administration, and thorough conceptualisation of social anxiety, including overall and subscale social anxiety scores. In the current study, Fear subscale scores ranged from 5 to 64 (*M* = 28.25*, SD* = 12.12), Avoidance subscale scores ranged from 2 to 60 (*M* = 25.95*, SD* = 12.80), and total scores ranged from 9 to 120 (*M* = 54.47*, SD* = 24.56). Here, the total scores were used to operationalise social anxiety. These total scores are higher than those obtained by Caballo, Salazar, Irurtia, Arias, and Nobre (2013) who, with a large university sample, found a mean LSAS-SR score of 42.19 for males and 45.73 for females.

Although not directly important for the study, generalised anxiety and depression were measured to provide a more informed characterisation of the sample. To achieve this, the Depression Anxiety Stress Scale-21 (DASS-21) was employed. Across 21-items, participants are asked to rate the degree to which each symptom has applied to them over the past week. Ratings are made on a 4-point Likert scale from 0 (never) to 3 (almost always). Separate scores are calculated for depression, anxiety, and stress, each ranging from 0 to 42. The DASS-21 has been found to have good convergent, discriminant, and construct validity (Crawford & Henry, 2003; Henry & Crawford, 2005; Lovibond & Lovibond, 1995) and reliability (Antony, Bieling, Cox, Enns, & Swinson, 1998; Brown, Chorpita, Korotitsch, & Barlow, 1997; Crawford & Henry, 2003; Lovibond & Lovibond, 1995). The Depression scores ranged from 0 to 42 (*M* = 10.20, *SD* = 8.87), anxiety ranged from 0 to 34 (*M* = 8.48, *SD*=7.90), and stress ranged from 0 to 40 (*M* = 13.99, *SD* = 9.39).

Procedure and Design

On each trial, a pair of faces was presented, and each face could appear on either the left or the right side of the screen. The conditions included happy-neutral, happy-angry, and angry-neutral pairings. It was always either the happy or angry face that was cued, either validly (the probe was in the cued location) or invalidly (the probe was in the location of the non-cued face). Thus, the design was 2 (target expression: angry or happy) x 2 (distractor expression: emotional or neutral) x 2 (validity: valid or invalid) design.

An additional "Incorrect cue" condition was included. Here, pairs of faces were happy-neutral or angry-neutral. The cue did not match the faces presented, and the probe appeared in the locus of the emotional expression. This was included as an exploratory condition to test where participants' attention would be allocated when the cued expression was not present. For example, if participants received a cue of "happy" but were then presented with an angry-neutral face pair, would their attention be captured by the un-cued angry face or would they only attend to emotional faces that match their top-down goal? The incorrect cue condition was not part of the main factorial analysis but was analysed separately, since it did not have a corresponding valid condition.

In this study, participants completed the demographic questions, the computer task, and then the LSAS and DASS-21. The computer task included an initial 50 practice trials and then 360 experimental trials with 8 rest breaks. Trials were randomised throughout the experiment with the constraint that the cued face was predictive of the probe location on 75% of trials. An equal number of happy-target and angry-target trials were included. On each trial, the two expressions presented were taken from the same model so that the images were matched for facial properties. The identity of the face on each trial was randomly selected with the constraint that the same proportion of male and female images were included in each condition.

On each trial, participants were presented with a black screen with a central fixation cross for 500ms (see Figure 1). The cue word, written in the centre of the screen ("Angry" or "Happy"), was then presented for 1000ms and was followed by a black screen with a fixation cross for 1000ms. Participants were instructed to orient their attention to the cued facial expression when it appeared and that doing so would help them perform the task more quickly. The faces were presented for 200ms, one to the right and one to the left of fixation. After they offset, a probe (the letter “E” or “F”) was presented for 300ms in the locus of one of the faces (equally likely to be each letter and equally likely to appear on the left or the right of the screen). Participants were asked to indicate the identity of the probe (an E or F), with a keyboard press as accurately and quickly as possible (“z” and “/” keys were marked as “E” and ‘F” on the keyboard, respectively). Once participants made a keyboard press, the next trial began. RTs were measured as the duration between the onset of the probe letter and participants’ key press.

Although 500ms image presentation is the most commonly employed duration in the literature, a 200ms duration was selected in the current study so as to minimise participants’ ability to make saccades in that timeframe. In addition, during pilot testing, participants reported that they were able to consciously perceive images at 200ms but not at quicker presentations. The probe presentation of 300ms (as opposed to visible until response) was selected during pilot testing to encourage participants to make quick attentional shifts (so as not to miss seeing the probe).

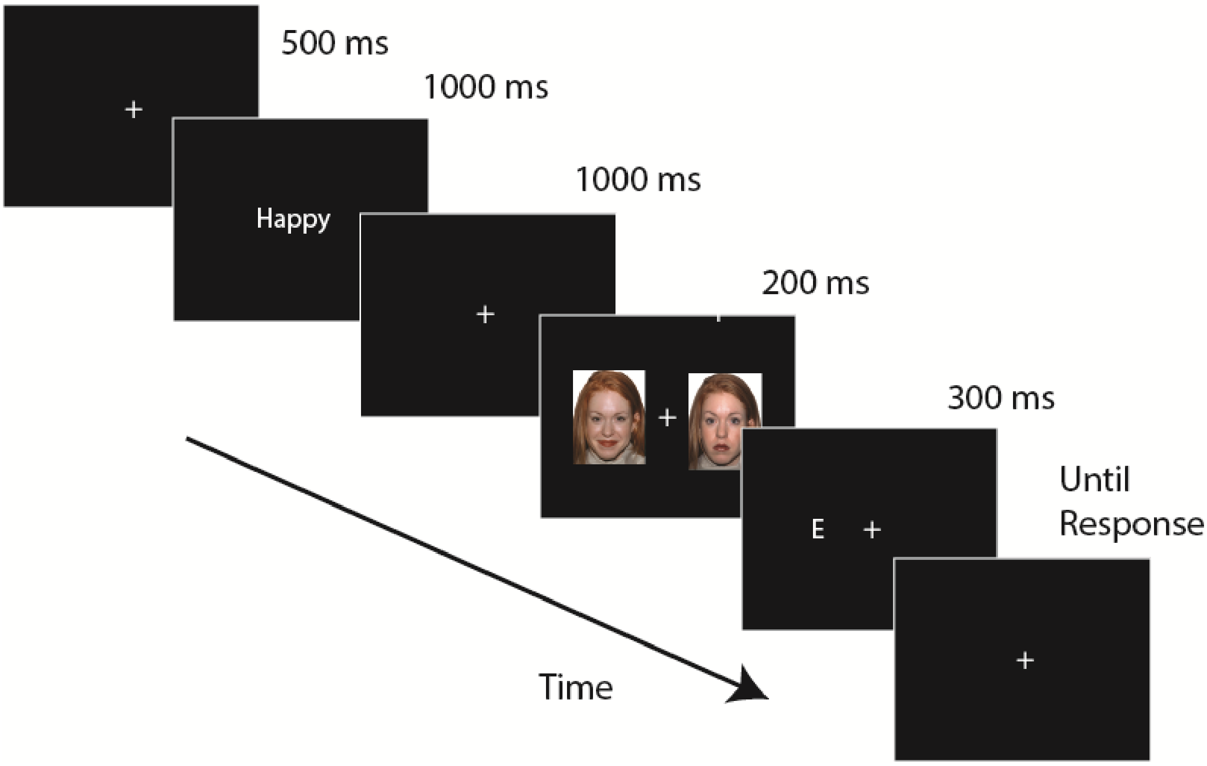

Figure 1. Schematic of a trial. This is an example of a valid trial, in which participants receive a "Happy" cue and then view a happy face paired with a neutral face and the probe appears in the locus of the happy face. Note that consent to use these particular face images for research and reproduction for publication was granted by Nim Tottenham to Hannah Boal (now Delchau) via email on July 9, 2016.

Results

Data Analysis

Data from five participants were excluded for having chance-level accuracy on the dot-probe task and data from six participants were excluded as RTs were outliers (z-score > 3.29). Therefore, data from 99 participants were included in the analyses. Trials in which participants made an invalid key press (i.e., hit a key that was not 'E' or 'F') or responded quicker than 100ms or slower than 2.5 standard deviations from their average RT were also excluded, consistent with previous research using RT (e.g., Goodhew, Freire, & Edwards, 2015; Goodhew & Plummer, 2019; Lester et al., 2019; van den Herk et al., 2012; Yoon et al., 2017). This accounted for on average 2.33% of participants' data. Accuracy and RTs for the correct trials were then calculated. Mean accuracy on the probe task was 90.85% (*SD* = 5.69%) and RT was 661.14ms (*SD* = 106.07ms). Since social anxiety is considered a continuous variable in the population, it was measured and analysed as continuous in the current study (see DeCoster, Iselin, & Gallucci, 2009). Furthermore, to increase interpretability and reduce multicollinearity, each participant's social anxiety score was centred around the grand mean (see Tabachnick & Fidell, 2013). Raw data can be found here: https://osf.io/unzw4/.

Accuracy. While RT was the primary measure of interest, accuracy was also examined to assess for any potential speed-accuracy trade-offs. To assess accuracy data, a 2 (target expression: happy or angry) x 2 (distractor expression: neutral or emotional) x 2 (validity: valid or invalid) ANCOVA was conducted with the continuous predictor variable of social anxiety. The effect of target expression was not significant, $F(1, 97) = 3.59$, $p = .061$, $\eta_p^2 = .036$, Cohen's $d = .39$[1]. There was, however, a significant interaction between target expression and validity, $F(1, 97) = 5.36$, $p = .023$, $\eta_p^2 = .052$, $d = .47$. A subsequent ANCOVA with one RM factor (validity: valid versus invalid) was performed with the continuous predictor of social anxiety on (a) average accuracy for when the target face was happy, and (b) average accuracy for when the target face was angry. This revealed that when the target face was happy, there was no significant difference in accuracy between the valid versus invalid trials ($F<1$, $d = .06$). In contrast, when the target was angry, there was a significant main effect of validity, $F(1, 97) = 8.10$, $p = .005$, $\eta_p^2 = .077$, $d = 0.58$, such that responses were on average more accurate for invalid ($M = 92\%$) versus valid ($M = 91\%$) trials. No other effects were significant (*p*s > .269, *d*s < .23).

Reaction time. Only trials on which participants correctly identified the probe were included in the RT analysis. To analyse the RT data, a 2 (target expression: happy or angry) x

2 (distractor expression: neutral or emotional) x 2 (validity: valid or invalid) ANCOVA was conducted with the continuous predictor variable of social anxiety. A main effect of validity was found, $F(1, 97) = 34.18$, $p < .001$, $\eta_p^2 = .261$, $d = 1.19$, as participants were quicker on the valid trials ($M = 657$ ms) compared with the invalid trials ($M = 676$ ms). This greater response efficiency for valid trials held when the dependent variable was an inverse efficiency score (IES), instead of RT, to account for the slight increase in accuracy observed on the invalid trials (IES = RT / (1 - proportion of errors, see Townsend & Ashby, 1978, 1983; for a discussion see Bruyer & Brysbaert, 2011). This demonstrates that participants complied with the instructions to use the top-down cue, and that this was effective in orienting their spatial attention.

The key theoretical question was whether participants with social anxiety would either have reduced attentional control, or whether any deficit would be selective to when threatening information serves as the distractor. Generic reductions in top-down control would be evidenced by reduced orienting in response to the top-down cue irrespective of the cued or distracting facial expression, as indicated by an interaction between social anxiety and validity. The selective deficit would instead be evidenced by reduced orienting to the cued expression when the distracting face was threatening (unique to when the *happy* face was cued and the non-target paired stimulus was *angry*), as indicated by a higher-order interaction between social anxiety, validity, distractor expression, and target expression. The interaction between validity and social anxiety was not significant ($F < 1$, $d = .06$). There was, however, a significant four-way interaction among target expression, distractor expression, validity, and social anxiety, $F(1, 97) = 7.14$, $p = .009$, $\eta_p^2 = .069$, $d = .54$. The effects of distractor expression, validity, and social anxiety was then assessed separately for each target expression (i.e., happy or angry).

For *angry-target faces*, there was a validity effect, $F(1, 97) = 24.31$, $p < .001$, $\eta_p^2 = .200$, $d = 1.0$, with faster RTs on valid ($M = 658$ms) compared with invalid trials ($M = 677$ms). No other main or interaction effects were indicated ($ps \geq .438$ and ds < .16 for interactions with social anxiety). In addition, an analysis with IES scores confirmed that responses were significantly more efficient for valid than for invalid trials. Altogether, this suggests that social anxiety was not associated with differences in attending to the angry faces, and instead all participants were able to use top-down attention to orient their attention to the angry faces.

However, for *happy-target faces*, a three-way interaction was revealed among the factors distractor expression, validity, and social anxiety, $F(1, 97) = 9.38$, $p = .003$, $\eta_p^2 = .088$, $d = .62$. To disentangle this three-way interaction, the effects of validity and social anxiety and their interaction were assessed separately for the two different distractor expressions (angry or neutral) presented with the happy face targets. This showed that for happy-neutral face pairs, there was a significant effect of validity, $F(1, 97) = 11.04$, $p = .001$, $\eta_p^2 = .102$, $d = 0.67$, with faster RTs for valid trials ($M = 655$ms) compared with invalid trials ($M = 673$ms). The interaction between validity and social anxiety was not significant, $F(1, 97) = 3.27$, $p = .074$, $\eta_p^2 = .033$, $d = .57$, indicating that all participants demonstrated an equivalent cueing effect irrespective of level of social anxiety.

In contrast, analyses revealed an overall validity effect for happy-angry trials, $F(1, 97) = 16.80$, $p < .001$, $\eta_p^2 = .148$, $d = .83$, with faster RTs for valid trials ($M = 657$ms) compared with invalid trials ($M = 678$ms), as well as a significant interaction between validity and social anxiety, $F(1, 97) = 5.34$, $p = .023$, $\eta_p^2 = .052$, $d = .47$. To illustrate this interaction, a cueing score was calculated for each participant as: invalid RT *minus* valid RT (where scores above zero indicate that participants could shift attention toward the cued happy face). As shown in Figure 2, participants with higher levels of social anxiety had lower cueing scores, indicating that they had difficulty shifting attention to the cued happy face on happy-angry trials. Indeed, a significant negative Pearson correlation was found between social anxiety and the cueing score for happy cued faces on happy-angry trials, $r = -.29$, $p = .023$, $d = .61$.

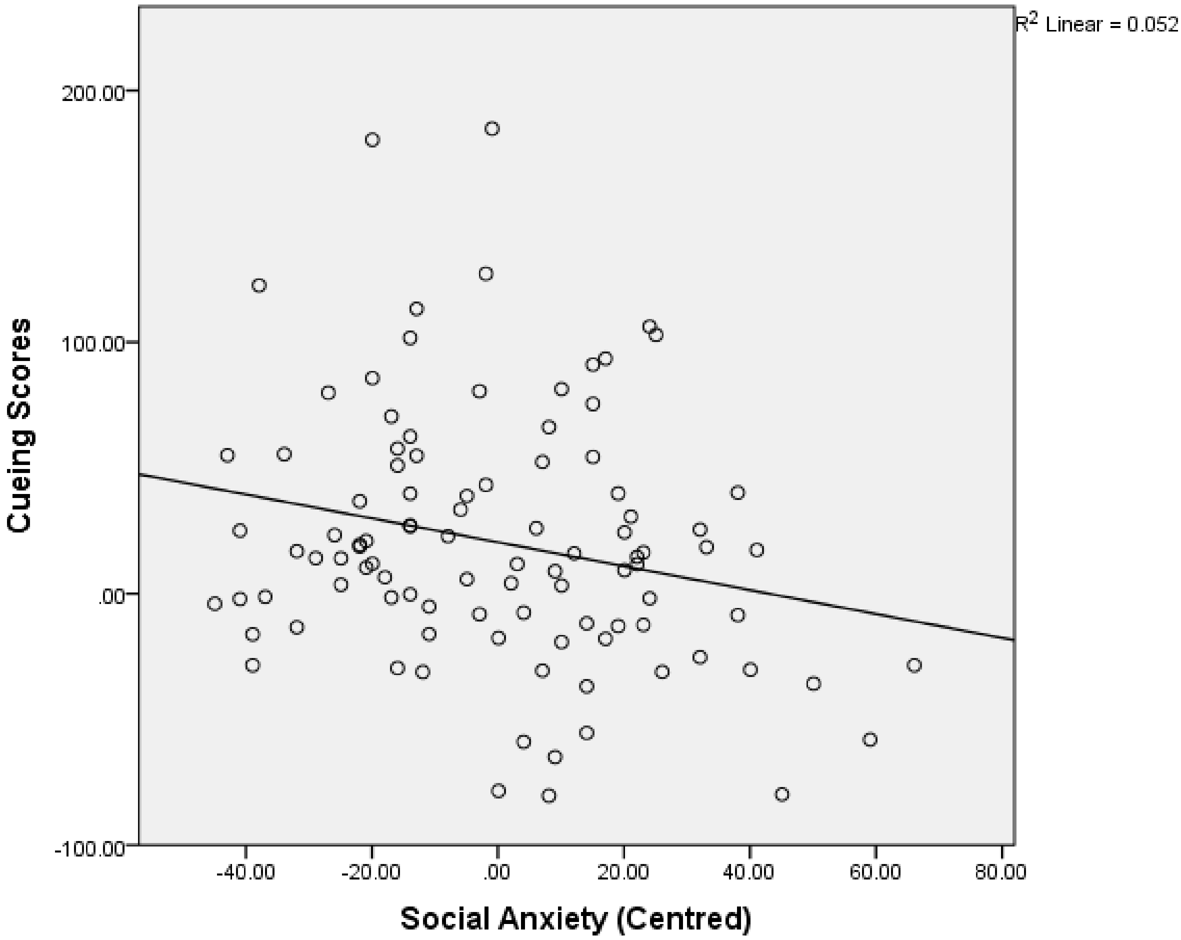

Figure 2. The relationship between social anxiety (centred) (x-axis) and cueing scores (in ms) (y-axis) toward cued happy faces on happy-angry face trials.

The psychometrics of the social anxiety score were reported in the methods section, but the reliability of the dot-probe is less well-established. A reasonable estimate of reliability can be obtained by comparing scores from one half of trials to the other (see Goodhew & Edwards, 2019, for practical recommendations). Here, we computed values for the first and second half of trials and submitted these to a 2 (half) x 2 (target expression) x 2 (distractor expression) ANCOVA with social anxiety as the continuous covariate. This revealed that there was a main effect of half, such that RTs were quicker in the second half versus the first half of trials, reflecting a generic and commonly-observed order effect. Order did not interact with any other main effects or interactions, whereas both the main effect of validity ($p < .001$) and the four-way interaction among target expression, distractor expression, validity, and social anxiety ($p < .028$) remained significant. In other words, the pattern of results was stable between the first and second half of trials. Similarly, even when the cueing scores (difference scores) plotted in Figure 2 were the dependent variable, experiment half yielded no reliable effect ($p = .174$), indicating that these scores were stable across the experiment. This is quite reassuring, given the evidence for some dynamic components to attentional bias scores (see Cox, Christensen, & Goodhew, 2017; Zvielli, Bernstein, & Koster, 2015), which can undermine aggregate-score level reliability. It could be that the specific instructions employed in the modified version of the dot-probe here (i.e., instructions to attend to a specific face, rather than passive viewing of faces) may contribute to improved reliability of the task.

Figure 2 shows that there is an inverse relationship between social anxiety and cueing toward happy faces in the presence of an angry face distractor. However, it would be useful to understand more precisely how this cueing effect is affected at different levels of social anxiety. To this end, the significance of the cueing effect was examined for different groups of participants according to established cut-offs on the LSAS. Note that for the following analyses only we deviate from our previous usage of social anxiety as dimension, and for the purposes of this analysis are considering scores in relation to possible diagnosis of Social Anxiety Disorder. For participants scoring below the cut-off for probable social anxiety (LSAS < 60), the cueing effect was significant, $F(1, 55) = 18.31$, $p < .001$, $\eta_p^2 = .250$, $d = 1.15$, with faster RTs on valid ($M = 646$ms) compared with invalid trials ($M = 676$ms). For participants scoring in the probable social anxiety range (LSAS = 60-90), the cueing effect was not significant, $F(1, 34) = 4.07$, $p = .052$, $\eta_p^2 = .107$, $d = 0.69$. Participants scoring in the highly probable social anxiety range (LSAS > 90), also did not have a significant cueing effect, $F(1, 7) = 2.80$, $p = .138$, $\eta_p^2 = .286$, $d = 1.3$. This, therefore, indicates that participants with high levels of social anxiety were not able to orient to the cued happy faces when it was paired with the angry face.

Gender effect. Previous research has found some evidence of faster and more accurate detection of angry expressions for male faces and of happy expressions for female faces (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007), and that female observers have superior facial expression recognition (Hall, Hutton, & Morgan, 2010; Rahman, Wilson, & Abrahams, 2004). To test if face gender and participant gender impacted results, a 2 (face gender: female or male) x 2 (target expression: happy or angry) x 2 (distractor expression: neutral or emotional) x 2 (validity: valid or invalid) ANCOVA was conducted with the continuous predictor variable of social anxiety and the between-subjects factor of participant gender (female or male). No significant main or interactive effects were found for face gender (ps $\geq .132$) or participant gender (ps $\geq .157$).

Incorrect-cue trials. For incorrect-cue trials, the cue could either be “Happy” in the context of an angry-neutral face pair or it could be “Angry” in the context of a happy-neutral face pair. This provided an additional check that participants’ attention was not captured by the emotional face on happy-neutral and angry-neutral face pair trials but that they were only orienting to the correctly cued facial expression. That is, quick responding to the probe replacing these un-cued emotional faces would indicate bottom-up attentional capture. Conversely, if responding was slower and on-par with the other invalid conditions, it would indicate that participants were able to ignore these emotional faces. To test this, data from valid happy-neutral and angry-neutral trials, which were previously used in the main analysis, were also used in this analysis. A 2 (target expression: happy or angry) x 2 (validity: valid or incorrect-cue) ANCOVA was conducted with the continuous predictor variable of social anxiety. This revealed a main effect of validity, as participants were significantly faster in the valid condition (M = 655ms) compared with the incorrect-cue condition (M = 670ms), $F(1, 97) = 19.77$, $p < .001$, $\eta_p^2 = .169$, $d = .90$).

A significant interaction was also found between social anxiety and target expression, $F(1, 97) = 5.26$, $p = .024$, $\eta_p^2 = .051$, $d = .46$). Next, two ANCOVAs with validity and social anxiety as factors were performed, one for when the angry face was the target, and one for when the happy face was the target. When the angry face was the target, there was a significant main effect of validity ($p = .001$), which did not interact with social anxiety ($p = .074$), and when the happy face was the target, there was a significant main effect of validity ($p = .001$), which did not interact with social anxiety ($p = .179$). That is, despite the significant three-way interaction, there was no evidence that the interaction between validity and social anxiety differed as a function of which face was the target, and so no further analyses were conducted or conclusions drawn[2]. In sum, data from the incorrect-cue-trials indicate that, on the happy-neutral and angry-neutral trials, participants' attention was not captured by emotion *per se* (i.e., regardless of the top-down goal) but, instead, oriented to the probe faster when its location matched their top-down goal.

Selection history effect. Finally, to test for effects of selection history, validity effects were compared between repeat and switch trials. On switch trials, participants had to shift their attention toward a different cued expression, as compared to the previous trial. By comparison, repeat trials were trials in which participants were cued to the same expression as on the previous trial. Trials were only included in these analyses if the previous trial was valid. The reason for this was that for valid trials, shifting toward the cued face was "rewarded" as the probe was presented in the locus of the cued face. Two additional participants' data were excluded as they had 0% accuracy in one of the conditions. Therefore, data from 97 participants were included in the following analyses.

To test the effect of selection history, a 2 (target expression: happy or angry) x 2 (validity: valid or invalid) x 2 (repetition: repeat or switch) ANCOVA was conducted with the continuous predictor variable of social anxiety. The analysis revealed a significant effect of repetition, $F(1, 95) = 4.48$, $p = .037$, $\eta_p^2 = .045$, $d = .43$, whereby participants were faster on repeat trials (M = 655ms) compared with switch trials (M = 672ms). All interactions with repetition were non-significant ($ps \geq .210$), suggesting that, although repetition of the same target resulted in faster responding to the probe generally, it did not increase the validity effect. Therefore, selection history did not improve participants' ability to shift attention to the cued expression.

Discussion

The aim of the present study was to investigate the manner in which individuals who are relatively higher in social anxiety differ in their capacity to exert attentional control when presented with emotional stimuli, as compared to individuals relatively lower in social anxiety. It was found that individuals with high levels of social anxiety could attend to the cued facial expressions on most trials, suggesting that socially anxious individuals, at least in part, exert top-down attentional processes when orienting to emotional facial expressions. That is, individuals with social anxiety did not show a generic inability to use top-down attention. Instead, the deficit was more selective as individuals with high levels of social anxiety exhibited some deficits in top-down attention when orienting attention to happy expressions paired with angry faces. These results are discussed in more detail below.

Is Social Anxiety Associated with Deficits in Top-Down Attention?

The current study revealed that participants could orient their attention toward angry faces and were equally efficient at doing so irrespective of their level of social anxiety.

Similarly, participants could orient their attention toward happy faces when they were paired with neutral faces. Thus, it does not appear to be the case that individuals with social anxiety have a generically poorer ability to use top-down attention in all instances. However, higher levels of social anxiety were associated with a reduced ability to shift attention to a *happy face* when the non-target face was *angry*.

One of the conditions in this study (incorrect-cue condition) cued an expression that was not subsequently presented. For example, participants may have been instructed to attend to a happy face but were instead presented with an angry-neutral pair. RTs in this condition indicated that participants' attention was not captured by the surprising emotional face, which indicates that top-down attention can prevent attentional capture by an emotional face. This effect was found irrespective of participants' levels of social anxiety. Interestingly then, high levels of social anxiety were associated with difficulties orienting to happy faces paired with angry faces, but these participants did not appear to have difficulties inhibiting attention to irrelevant angry faces on angry-neutral trials.

These results are consistent with Attentional Control Theory (Eysenck et al., 2007), which hypothesises that, in the presence of threat-related stimuli, anxiety will be associated with greater impairments in task efficiency and/or performance when the task is demanding as this utilises greater attentional resources. In addition, previous research has emphasised the link between high social anxiety and deficits in attentional control (Moriya & Tanno, 2008; Wieser, Pauli, & Muhlberger, 2009). We suggest that trying to shift attention to a happy face while also suppressing bottom-up capture of attention to an angry face is a demanding task, which is why higher levels of social anxiety were associated with poorer top-down control. By contrast, simply having to inhibit attention to the angry faces in the incorrect-cue condition may be an easier task, which may be why no effects of social anxiety were found in this condition. These findings indicate that, for more complex stimuli, high levels of social anxiety are associated with deficits in orienting to positive stimuli in the presence of threatening stimuli. In everyday life, heavy demands are placed on the attentional system. For example, when giving a speech, people may need to read their notes, monitor the time, switch the slides in their slideshow presentation, and make eye-contact with the audience. These deficits in top-down control for socially anxious individuals may, therefore, be even more apparent in ecologically valid environments, such as in this situation.

It should be noted that we have interpreted spatial attentional cueing scores as reflecting top-down attentional control. This is because a non-zero cueing score implies that the participant complied with the instruction to attend to the cued facial expression, even when faced with other potentially more salient information in the display (as in the case where participants were instructed to attend to the happy face, but an angry face was displayed as the nontarget). It is standard practice in the attention literature to interpret attentional orienting of this nature as reflecting “attentional control settings” (see seminal paper by Folk et al., 1992), or more recently “top-down attentional control” (see review by Awh et al., 2012). Logically, therefore, when such cueing was diminished, we interpreted this as reflecting impoverished or impaired top-down attentional control. We believe that this is a legitimate interpretation that is well-grounded in prior empirical evidence and conceptual thought about such cognitive processes. Future research should consider inclusion of an independent measure of attentional control as provided, for example, by the Attentional Control Scale (ACS) (see Derryberry & Reed, 2002). Based on our interpretation of the experimental data, we predict that individuals who have lower self-reported attentional control would be more susceptible to interference in instantiating their top-down set, as revealed by diminished cueing scores.

In a similar vein to the current study, Basanovic and MacLeod (2017) employed a dot-probe task in which participants were given a top-down goal on each trial. This goal could be to either attend to or avoid real-world negative images. As with the current study, these researchers found that participants could use top-down attention to orient to the cued images. No differences in performance were found between participants with low and high trait anxiety, unlike the findings from the present study. However, there are a number of key differences between the current study and Basanovic and MacLeod's study that could account for why these researchers did not find deficits in performance for anxious participants. First, the current study utilised a 200ms image presentation time whereas Basanovic and MacLeod utilised a presentation time of 1000ms and, so, perhaps anxious participants only have deficits in initial, rapid orienting of attention but these deficits may no longer be observable at later stages of attention. Second, Basanovic and MacLeod investigated *trait* anxiety, whereas the current study investigated *social* anxiety. In addition to these being distinct psychological concepts, which in and of itself could reasonably be expected to lead to different patterns of results, this difference in the form of anxiety targeted led to a number of critical methodological differences in the designs of the two studies. That is, third, the current study found that anxious participants' deficits were selective to when happy and angry faces were directly paired together. Basanovic and MacLeod did not directly pair negative and positive images together as these images were instead always paired with an abstract image. Thus, in their study there was never the direct competition between positive and negative images which was the condition that differentiated between individuals with different levels of social anxiety here. Fourth, the stimuli used were different (facial expressions versus real-world scenes). Further research will be required to systematically test which of these differences between the current study and Basanovic and MacLeod's (2017) study accounts for the contrasting findings.

It is worth acknowledging that while we unambiguously attribute the present results to a deficit in orienting to happy faces in the presence of a threatening (angry) distractor, it remains to be seen whether this effect generalises to other types of negative distractors or is specific to threat. Future research could test this possibility by including a sad target and distractor. In a similar vein, angry faces imply a *social* threat. It is conceivable that individuals with high levels of social anxiety are selectively sensitive to this type of threat, but not other types of threat (e.g., snakes and spiders). Further study in this area would provide further insight into the specificity of the top-down attentional deficit associated with social anxiety.

Clinical Implications

Throughout this manuscript we have conceptualized social anxiety as a dimensional trait variable in the population, without necessarily invoking diagnostic criteria. However, high levels of self-reported trait social anxiety are likely to correlate with formal diagnoses, and even for those that do not, individuals may experience significant distress and can benefit from therapeutic approaches in the absence of a formal diagnosis. Here we discuss the clinical or therapeutic implications of the present work, and contextualize it in relation to previous research.

Since an attentional bias to threat is conceptualized as a maintaining factor for social anxiety, a growing body of research has attempted to develop therapeutic strategies and techniques to reduce this bias and, thus, reduce symptoms of social anxiety. This is known as attention bias modification (ABM; for a review, see Heeren, Mogoase, Philippot, & McNally, 2015). The most common method is a variant of the visual dot-probe task, in which probes nearly always (e.g., 95% of trials) follow non-threatening stimuli (e.g., neutral or happy faces). This task is designed to train individuals' attention away from threatening stimuli (e.g., angry or disgust faces) and, instead, toward neutral or positive stimuli. Although some studies have found that ABM results in reduced social anxiety (Amir et al., 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008; Heeren, Reese, McNally, & Philippot, 2012;

Schmidt, Richey, Buckner, & Timpano, 2009), these results have not been replicated by other studies (Boettcher, Berger, & Renneberg, 2012; Boettcher et al., 2013; Carlbring et al., 2012; Julian, Beard, Schmidt, Powers, & Smits, 2012; McNally, Enock, Tsai, & Tousian, 2013). In fact, Boettcher et al. (2013) found that participants trained to attend to threat had the greatest improvements in social anxiety symptoms compared with the attend-positive and control condition, and Klumpp and Amir (2010) found that both attend-negative and attend-neutral conditions resulted in reductions in anxiety compared with a control condition. These mixed findings highlight the fact that the underlying mechanisms of this anxiety-related threat bias are not well understood.

The present research indicates that individuals possess an important resource which means that they are not always at the mercy of salient stimuli in the environment – namely top-down attentional control. However, it also revealed that individuals with high levels of social anxiety have a reduced ability to execute attentional control in the face of non-task-relevant threat. Targeting this deficit specifically may lead to improved therapeutic outcomes. The ability to regulate one's attention derives from working memory capacity (e.g., Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003). This suggests that individuals with high levels of social anxiety may therefore benefit from training programs aimed at enhancing their working memory capacity, in particular in the context of non-task-relevant threat.

Does Selection History Impact the Threat Bias?

Selection history refers to the lingering effects of information from past trials (Awh et al., 2012). For example, if a participant responded to a red target on the previous trial, they may get captured again by a red object even if it no longer matches their top-down goal. Selection history was measured in the current study by comparing trials that repeated the same facial expression target (happy or angry) with those on which the facial expression target switched from the previous trial. This study found a general speeding effect for repeat trials compared with switch trials toward the probe. However, repetition did not interact with validity and, therefore, there was no evidence that repetition improved participants' ability to shift attention to the cued face relative to the distractor face. Furthermore, social anxiety did not interact with selection history effects.

The fact that selection history effects did not impact attentional orienting may appear at odds with the broader literature, but there are a number of reasons why selection history effects were not observed here. Of theoretical interest is the possibility that selection history effects may be weaker or absent for faces. This could be because a face is a more complex visual object than the simple geometric shapes used in previous research. Alternatively, it could be because facial expressions represent a *category* of object (e.g. happy faces) rather than a single individual exemplar (e.g., a particular happy face). Selection history effects may operate at the level of individual exemplars rather than object categories.

In contrast, selection history effects may occur for faces, but detection of such an effect may require a greater number of repetitions than used in the present study. While this is possible, multiple pieces of evidence speak against this as selection history effects have been observed for simple stimuli with the same number of repetitions present here (Belopolsky & Awh, 2016; Leonard & Egeth, 2008; Maljkovic & Nakayama, 1994; Mortier, Theeuwes, & Starreveld, 2005; Müller, Reimann, & Krummenacher., 2003; Theeuwes, Reimann, & Mortier, 2006; Theeuwes & Van der Burg, 2007; Zehetleitner, Krummenacher, Geyer, Hegenloh, & Müller, 2011). Altogether, the present results are promising in pointing to the imperviousness of more complex or category-level stimuli to the effects of selection history, but further research where selection history effects are compared for simple versus complex stimuli, and individual stimuli versus category-level groupings is required in order to answer this definitively.

Recently, Peschard and Philippot (2016) proposed that selection history may have an important role in attentional biases toward threat for social anxiety. That is, these authors speculated that since selection history is related to carry-over and lingering effects, it may contribute to patterns of rumination following social exposure which predispose individuals to social anxiety. Although we found no evidence for a relationship between self-reported social anxiety and repetition benefits, this does not necessarily mean that selection history does not play a part in social anxiety symptomatology. For instance, it is possible that the deficits observed for participants with high social anxiety may be overcome with selection history after further repetitions of the same target expression. Although this was beyond the scope of the current study, future research could conduct a trial-by-trial analysis to test the number of repetitions of the same cue that is required for socially anxious participants to be able to reliably shift attention toward happy faces in happy-angry face pairs.

Alternative Interpretation

Here, we tested if participants could follow a cued top-down goal of happy or angry faces and found a deficit in top-down control of attention. In doing so, an underlying assumption was that threat capture is due to bottom-up attention, which is consistent with an evolutionary perspective (Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010; Lang, Bradley, & Cuthbert, 1997; LeDoux, 1996; LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). However, another possibility is that participants with high levels of social anxiety may have had a chronic top-down attentional goal to attend to threat, which would have interfered with their cued top-down goal to attend to happy faces. Indeed, the role of top-down attentional beliefs is critical to Rapee and Heimberg's (1997) cognitive-behavioural model of social anxiety. According to this model, individuals' top-down beliefs that they must make a good impression on others and that others are inherently critical will drive orienting of attention to threat. It is, therefore, possible that socially anxious participants had difficulty orienting to cued happy faces, not because their attention was automatically driven to attend to threat, but because they had a top-down goal of attending to threat, which is chronically activated in social situations. Further research is needed to test these proposals. However, even if this is the correct interpretation, our overarching conclusion would still hold – socially anxious participants have a poorer ability to regulate their top-down control in the presence of threat.

Spatial versus Temporal Attention

The present study focussed on the mechanisms of *spatial* attention, that is, how and where attention is allocated across space. However, another important attentional process is *temporal* attention, that determines which stimuli are selected in time. A useful laboratory tool for examining the role of emotion in temporal attention is that of *emotion-induced blindness* (EIB). Here, a rapid serial visual presentation (RSVP) stream of images is presented, and participants' task is to identify the orientation of a neutral landscape image (rotated 90° to the left/right of vertical). Prior to the target, a critical distractor is presented which is either neutral or emotionally-evocative. Emotionally-evocative stimuli, both highly pleasant (i.e., erotica) and unpleasant images (e.g., mutilated bodies, scenes of attack) automatically capture attention even though they are not task-relevant, and impair participants' ability to perceive the target when it follows the critical distractor close in time (Most et al., 2005, 2007). While this effect is heightened in those with high levels of self-reported negative affect (Onie & Most, 2017), it also robustly occurs in the general population. Recent work shows that negative (angry) faces can produce emotion-induced blindness, even in non-anxious participants (Gutiérrez-Cobo et al., 2019). This contrasts with spatial-attentional phenomena which appear to be more selective to individuals high in anxiety (e.g., meta-analysis by Bar-Haim et al., 2007). Furthermore, it has been shown that spatial-attentional versus temporal-attentional threat-effects predict unique variance in negative affect (Onie & Most, 2017). Altogether, this suggests that it is important to consider how threatening stimuli influence the dynamics of spatial and temporal attention separately. In particular, it will be interesting for future work to determine if, for example, individuals high in social anxiety are more susceptible to emotion-induced blindness with angry faces.

Conclusion

In conclusion, in the typical dot-probe task, participants are not instructed to attend to any of the displayed facial expressions and, instead, the task measures naturally occurring biases in attention. Using this paradigm, most research indicates that socially anxious individuals have a bias toward threatening faces relative to neutral faces (Mogg et al., 2004; Pishyar et al., 2004). In the current study, participants were cued to happy and angry facial expressions to explicitly test the role of top-down attention in the process of attending to emotional faces. Building on the theoretical and clinical research of Bishop et al. (2007) and Eysenck et al. (2007), the current findings suggest that socially anxious individuals did not have a general top-down deficit but instead had selective difficulty orienting toward happy faces when paired with distracting threatening stimuli. The next avenue for research is to understand how this deficit in top-down attentional control can be overcome to further aid treatments of social anxiety.

Notes

1. Partial-eta squared values were converted to Cohen's d values using the calculators provided by https://www.psychometrica.de/effect_size.html#transform
2. Note that we are maintaining a consistent criterion for whether an effect or interaction is considered statistically significant (i.e., $p < .05$). This interaction was deemed to be non-substantive because subsequent follow-up tests of the interaction yielded non-significant (i.e., $p > .05$) results in relation to the social anxiety variable.

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Chapter Seven. Social Anxiety and Attentional Biases: A Top-Down Contribution?

Chapter Overview

Chapter Six demonstrated that participants with high levels of social anxiety had a selective deficit in top-down attentional control, as they had difficulty orienting to a cued happy face when paired with a distracting angry face. No other impairments in top-down attentional orienting were found. Chapter Seven investigates whether this bias to threat is due to overactive bottom-up attentional capture or a chronically activated top-down set to threat (that is not overridden when instructed to attend to positive emotion, as in Chapter Six).

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Author Contributions

- **Delchau** proposed the project.
- **Delchau** designed the experiment with contributions from Goodhew and Christensen.
- **Delchau** coded the computer task with contributions from Goodhew.
- **Delchau** collected the data.
- **Delchau** analyzed the data, with advice from Goodhew.
- **Delchau** produced the tables and figures.
- **Delchau** wrote the manuscript with editing provided by Goodhew and Christensen.
- After reviews were received from *Attention, Perception and Psychophysics*, **Delchau** refined the manuscript in response to reviewers' comments, with editing provided by Goodhew.

Social anxiety and attentional biases: A top-down contribution?

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Running head: Social anxiety and attentional biases

Abstract

Selective attention toward threatening facial expressions has been found to precipitate and maintain symptoms of social anxiety. However, the automaticity of this bias is under debate. In the present study, we aimed to test whether top-down (controlled) engagement and disengagement of attention toward threatening faces is associated with social anxiety. This was examined by testing the impact of a secondary working memory (WM) load on attentional biases. In a variation of the dot-probe task, participants' attention was initially cued to the left or right of fixation before an upright face paired with an inverted face was presented (displaying a disgust or neutral expression), and participants responded to a subsequently presented probe. The task was performed under no-load, low-load (one-digit memory task), and high-load (six-digit memory task) conditions. Social anxiety was not found to be associated with delayed disengagement from threat. However, surprisingly, high social anxiety was associated with an engagement bias *away from* threat, whereas low social anxiety was associated with a bias *toward* threat. These results were unaffected by the WM load manipulation. This indicates that engagement with threatening facial expressions has minimal contributions from top-down mechanisms, since it is likely that orienting to facial expressions occurs relatively automatically.

Keywords: selective attention, spatial attention, working memory load, social anxiety, dot-probe.

Social Anxiety and Attentional Biases: A Top-Down Contribution?

When interacting with our environment, we are bombarded with visual information, only a small amount of which can be consciously processed due to our limited perceptual resources (Desimone & Duncan, 1995; Kastner & Pinsk, 2004). Selective attention is, therefore, used to filter information so that the visual system can preferentially attend to important and relevant aspects of the visual environment. Consequently, selective attention is integral in shaping our perception of the world around us. One factor that exerts a powerful influence over selective attention is an individual's level of anxiety. For example, although healthy individuals may show a small bias for preferentially processing threatening stimuli (e.g., feared objects such as snakes) over neutral stimuli, this bias is heightened for individuals with anxiety. Indeed, this threat bias is viewed as a core cognitive component of anxiety and central to many contemporary conceptualisations of clinical anxiety disorders and their treatments (Cisler & Koster, 2010). For example, some longitudinal studies suggest that threat biases in childhood predict the development of anxiety disorders later in life (Shechner et al., 2012). Furthermore, threat biases are involved in the maintenance of anxiety, since attentional training to reduce threat biases also reduces anxiety (for a review, see Bar-Haim, 2010).

Given the sensitivity *of socially anxious* individuals to negative social evaluation, threatening facial expressions hold special clinical significance for this population (Rapee & Heimberg, 1997). According to Rapee and Heimberg's cognitive model, individuals with social anxiety are hypervigilant to monitoring their external environment for signs of negative evaluation from others. For example, when giving a speech, a socially anxious individual will be more likely to scan their audience for facial signs of criticism or disapproval (e.g., frowning), which then increases their level of anxiety. This model is supported by research findings that socially anxious individuals show biased attention toward photos depicting angry, hostile, and disgust expressions compared with neutral facial expressions (Mogg, Philippot, & Bradley, 2004; Pishyar, Harris, & Menzies, 2004).

In the present study, we aimed to test whether these threat biases are driven by bottom-up or top-down attention. *Top-down* attention refers to the voluntary allocation of attention toward particular objects, features, or spatial locations based on one's current goals. For example, when looking for a friend in a crowd, knowing that the friend is wearing a red scarf allows one to selectively attend to red objects. By contrast, *bottom-up* attention is an involuntary, rapid, and inflexible process that selects visual information based on the salience of the stimulus features. For example, while searching for a red object, an individual's attention may be captured by a flashing billboard even though the person had no intention to attend to that stimulus.

Traditionally, threat biases have been conceptualised as bottom-up. In line with this notion, evolutionary models posit that being able to respond to threat through bottom-up processing is adaptive (Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010; Lang, Bradley, & Cuthbert, 1997; LeDoux, 1996; LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). That is, being able to detect a threatening stimulus in the environment has evolved in the human species to facilitate survival (e.g., a fight or flight response to a predator) and is part of an automatic vigilance mechanism (Pratto & John, 1991). In support of this argument, research has shown that humans can engage early and rapid detection of low-level perceptual features associated with threatening images (LoBue, 2014; LoBue & DeLoache, 2011; LoBue & Larson, 2010). For example, using a visual search task, LoBue (2014) observed a bias toward curvilinear shapes (representative of snakes) compared with rectangular shapes. In addition, this bias to curvilinear shapes increases after watching a fearful film clip (LoBue, 2014), indicating that anxiety increases the detection of threat-relevant, low-level perceptual features. Similarly, biases for angry face features, such as the downward “V” shape of the eyebrows, have been found in both child and adult populations, which these authors argue indicates an evolved attentional bias for threatening stimuli (LoBue & Larson, 2010).

However, in opposition to this argument, research has found that threat detection does not always occur automatically. Visual search requires participants to detect an object or feature as rapidly as possible amongst distractor objects in a visual array. Using this task, past research has found that socially anxious individuals detect angry faces among neutral distractors more rapidly than happy faces among neutral distractors (Gilboa-Schechtman, Foa, & Amir, 1999). However, search times have been found to increase with added distractors (Eastwood, Smilek, & Merikle, 2001; Öhman, Lundqvist, & Esteves, 2001). Since automaticity in visual search has traditionally been conceptualised as being invariant to the number of distractors in the display (Treisman & Gelade, 1980), this suggests that the processing of threatening faces is not purely bottom-up as it requires attentional resources (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Vuilleumier & Righart, 2011).

The involvement of attentional resources in this process of orienting toward threat can be assessed with the use of working memory (WM) load. Previous research has found that tasks with high WM loads result in greater interference effects from visual distractors compared with low WM load tasks (de Fockert, Rees, Frith, & Lavie, 2001). Thus, voluntary, top-down selective attention can be impaired by WM load. By contrast, bottom-up attention is unaffected by WM load (e.g., Jonides, 1981). In the present study, therefore, we imposed a WM load to selectively impair the top-down attentional system without impacting bottom-up mechanisms.

Researchers employing WM load tasks have found some evidence that attentional biases can be overcome under high WM load (Pessoa et al., 2002; Van Dillen & Koole, 2009). For instance, Van Dillen and Koole employed an interference paradigm, in which participants viewed faces of varying expressions and were asked to indicate the gender of the faces. This study found that, as compared with happy faces, angry faces resulted in slower gender naming, but only under low-load. These researchers propose that, under high-load, negative stimuli do not capture attention because WM is fully engaged by the task. Only under low-load, when there are spare attentional resources, can negative stimuli are prioritised. However, this body of research has looked at interference effects from threatening stimuli that are presented individually at an attended location, rather than the capture of attention to the spatial location of a stimulus that is in competition with other stimuli elsewhere in the scene. Spatial attentional capture is particularly important to understanding threat biases for socially anxious individuals as they may cause individuals, when giving a speech for example, to attend to threatening faces in a top-down fashion, thus increasing their anxiety.

Recently, Judah, Grant, Lechner, and Mills (2013) assessed the top-down nature of the threat bias with socially anxious individuals by presenting participants with images of happy, disgust, and neutral facial expressions in a dot-probe task under three conditions: no, low, and high WM load. In the modified dot-probe task, two faces (e.g., one neutral and one negative) are presented on the computer screen, one to the left and one to the right of fixation. A probe (e.g., a letter) is then presented in the locus of one of the faces and participants are asked to respond to its identity. Faster reaction times (RTs) to respond to a probe appearing in the locus of a negative facial expression compared to a probe in the locus of a neutral facial expression indicates that participants' attention was captured by the negative face. This is known as a threat bias.

Judah et al. (2013) used a long presentation time for the faces (1000ms), which they claimed measured later attentional mechanisms of disengagement and avoidance. These researchers found that socially anxious individuals displayed avoidance of disgust expressions under no WM load but had difficulty disengaging attention under high WM load. However, one issue with this study, and that of the dot-probe design more generally, is that engagement and disengagement biases are conflated. Therefore, a threat bias can arise either due to enhanced engagement with that face or delayed disengagement from it. Although Judah et al. (2013) claimed that disengagement biases can be assessed using a long presentation time, this assumes that all participants initially shift their attention equally toward the threatening stimulus. If, however, individuals with higher levels of socially anxiety more readily engage with the threatening face, any attempt to measure the disengagement bias is conflated with engagement effects. Due to this issue, it cannot be determined whether the finding that social anxiety is linked to a threat bias is due to enhanced engagement or delayed disengagement effects.

Grafton and MacLeod (2014) and Rudaizky, Basanovic, and MacLeod (2014) have developed an elegant method for differentiating engagement biases from disengagement biases using a variation of the dot-probe task. In this design, on each trial participants viewed a target image (a threatening or neutral scene) paired with a non-representational image (abstract art) and participants' shifts of attention toward and away from the location of the target image was measured. Specifically, these researchers presented an initial cue (a small red line oriented horizontally or vertically) before the presentation of the faces. This cue was presented either on the left or right side of the screen and, therefore, secured participants' attention in the same location or opposite location to the target image. A disengagement trial was defined as a trial in which the target image was presented in the same location as the preceding cue, as participants were required to disengage their attention from the target to respond to a subsequent probe in the distal location. An engagement trial, by contrast, was defined as a trial in which the target was presented in the opposite location to the preceding cue, as these trials measured whether participants shifted their attention toward the target.

After the cue and faces were presented, a probe (similar in appearance to the cue) was presented in the locus of one of the faces and participants were asked to indicate whether the probe was the same or a different orientation to the cue. On 50% of trials, the probe appeared in the distal location to the target face and on 50% of trials, it appeared in the proximal location. Therefore, for engagement trials, faster RTs in the proximal probe position compared with the distal position, indicated that participants shifted their attention toward the target face. Importantly, these distal-proximal probe difference scores were compared between trials in which the target image was negative compared with when it was neutral, to measure if greater engagement toward threat occurred for anxious participants. Similarly, difference scores were used to measure the disengagement bias to test whether participants had greater difficulty shifting away from the target image and responding to the distally presented probe, compared with the proximal probe, when a negative target image was used compared with a neutral target image. Both Grafton and MacLeod (2014) and Rudaizky et al. (2014) found that high trait anxious participants, compared with low trait anxious participants, have engagement biases and delayed disengagement biases for threat.

Although it was published after data collection for the present study was complete, a recent study employed a similar design to measure engagement and disengagement biases for participants with low and high social anxiety (Grafton & MacLeod, 2016). On each trial, negative and neutral faces were paired together and these researchers found that participants with high social anxiety had a greater engagement bias toward negative facial expressions compared with participants with low social anxiety. Social anxiety was not found to be associated with difficulties disengaging from threat. These data indicate the importance, therefore, of differentiating these biases from one another. The present study will extend on Grafton and MacLeod’s research by testing whether these biases are driven by top-down or bottom-up attentional orienting (Corbetta & Shulman, 2002; Posner, 1980). Specifically, the present study includes an additional WM load task to test if attentional biases are affected by high WM load, which would indicate that they are driven by top-down attention.

Present Experiment

In the present study, we sought to investigate the contribution of top-down attention in the selective processing of threatening visual information for individuals with high social anxiety. This was tested using a variation of the dot-probe task (Grafton & MacLeod, 2014; Rudaizky et al., 2014), in which participants were presented with neutral and disgust facial expressions and their engagement with and ability to disengage from these faces were measured. The dot-probe task provides an opportunity to measure spatial attention, which is of particular clinical relevance to social anxiety and also allows for the separate analysis of engagement and disengagement biases. Engagement and disengagement biases were compared under three conditions: no WM load, low WM load, and high WM load. WM load was used to deplete top-down attentional resources. Under no and low WM load, it was expected that higher social anxiety would be associated with an engagement bias toward the disgust faces. If the engagement bias is driven by bottom-up attention, this bias would be unaffected by the load manipulation. However, if the engagement bias is driven by top-down attention, this bias would be attenuated under high WM load. Regarding disengagement effects, recent research has found that social anxiety is not associated with delayed disengagement from threat (Grafton & MacLeod, 2016). However, trait anxiety, which shares many similar features with social anxiety, has been found to be associated with delayed disengagement from threat (Grafton & MacLeod, 2014; Rudaizky et al., 2014). With this study, therefore, we aimed to elucidate whether social anxiety is associated with delayed disengagement from threat and, if it is, whether it is affected by WM load.

Method

Participants and Design

One hundred participants (53 female) were recruited from the Australian National University via online advertisement and the university electronic sign-up system and these participants completed the experiment in exchange for course credit or $30 payment. Participants all reported to have normal or corrected vision, their ages ranged from 17 to 36 years (M=22.43, SD=3.62) and 91 of them were right-handed. Participants' social anxiety scores, as measured by the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1989) ranged from 3 to 64 (M=26.18, SD=12.94). These scores are somewhat higher than would be expected based on the normative data of Heimberg, Mueller, Holt, Hope, and Liebowitz (1992), who found a mean of 19.9 on the SIAS in a community sample. Heimberg et al. (1992) defined the clinical cut-off for social phobia as equal to or greater than 34 on the SIAS, which reflected one SD above the mean score of the community sample.

Participants' depression scores on the depression component of the Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995) ranged from 0 to 39 (M=5.69, SD=5.79) and, as measured with the State-Trait Anxiety Scale (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), state anxiety ranged from 20 to 62 (M=33.7, SD=9.21) and trait anxiety ranged from 24 to 72 (M=42.55, SD=9.06). All participants provided written informed consent prior to participation and provided demographic information. Table 1 presents demographic and self-report scores for participants with low and high social anxiety, as calculated using a median split.

Table 1

Demographic and self-report scores for low and high social anxiety groups

	Participants *(Female)*	**Age** *M(SD)*	**SIAS** *M(SD)*	**DASS-D** *M(SD)*	**STAI-S** *M(SD)*	**STAI-T** *M(SD)*
Low social anxiety	50 (26)	22.26 (3.39)	15.72 (5.65)	3.66 (3.86)	30.10 (7.00)	36.54 (7.47)
High social anxiety	50 (27)	22.40 (3.66)	36.64 (9.10)	7.72 (6.67)	37.30 (9.79)	46.56 (8.79)

Images

Images of faces was taken from the FACES database (Ebner, Riediger, & Lindenberger, 2010), consisting of the neutral and disgust expressions from Set A of the young age range (ages 19-31). Since research has found a same-age facial recognition bias (Rhodes & Anastasi, 2012), the young age range faces were included in this study to match the average age of participants. On each trial the two faces presented were taken from the same face model so that they were matched for facial properties, and one image was presented upright and one image was inverted. Each image subtended 6.81 x 8.52° of visual angle.

Experimental Task

Participants completed the demographic questions, the SIAS, STAI, and depression items from the DASS, and then participated in the computer task. This experiment was conducted in a dimly lit room. Stimuli were presented on a cathode-ray tube (CRT) gamma-corrected monitor running at a 75Hz refresh rate. Viewing distance was set with a chinrest at 44cm. Stimuli were programed in Matlab using the Psychophysics Toolbox (Brainard, 1997) and the background was set to black.

The computer task consisted of three blocks of trials (no-load, low-load, and high-load) counterbalanced across participants. Each block consisted of 224 trials and so each participant completed a total of 672 trials. Before each block, participants completed five practice trials with corrective feedback.

In the low- and high-load conditions, a number was presented centrally on the screen at the beginning and end of each trial (see Figure 1). A single-digit number was used in the low-load condition and a six-digit number was used in the high-load condition. The digits in these numbers could range between 1 and 9 and were generated using a random number generator. On approximately half the trials the number presented at the end of the trial matched the one presented at the beginning and on approximately half of the trials it changed. In the high-load condition, the number could only change by one of the digits so the participant was required to remember all six digits to determine if it was the same or different. For the low-load task, the single-digit number was presented for 1000ms, whereas in the high-load task, the six-digit number was presented for 3000ms, which provided sufficient time to read the number strings. Participants were then asked to make a same/different keyboard press to indicate whether it matched the number presented at the beginning of the trial.

Regarding the main probe task, initially a blank screen was presented for 1000ms. On each trial two white rectangular outlines were initially presented, one to the left and one to the right of fixation for 1000ms. These rectangular outlines subtended 6.81 x 8.52° of visual angle and the width of the lines subtended 0.089°. A smaller red rectangle, subtending 1.70 x 2.13°, was also presented inside one of the white rectangles to indicate the location of the to-be-presented cue. The cue (a small red line) was then presented within the box for 200ms. This cue could be oriented horizontally or vertically and subtended a visual angle of 0.48° and had a width of 0.089°.

After these stimuli disappeared, two images of faces were presented for 500ms, one to the left and one to the right of fixation, such that they occupied the locations that the white rectangles previously occupied. After these faces offset, a probe (a small red line) oriented horizontally or vertically, which was identical in appearance to the cue, was then presented in the locus of one of the faces and was oriented horizontally or vertically. Participants made a keyboard press to report whether the orientation of the probe matched the orientation of the cue as quickly and accurately as possible. The variables (location, orientation, and image type) were randomised, with the restriction that an equal number of trials consisted of disengagement or engagement trials, negative or neutral upright photos, and that the probe was distal or proximal to the upright image

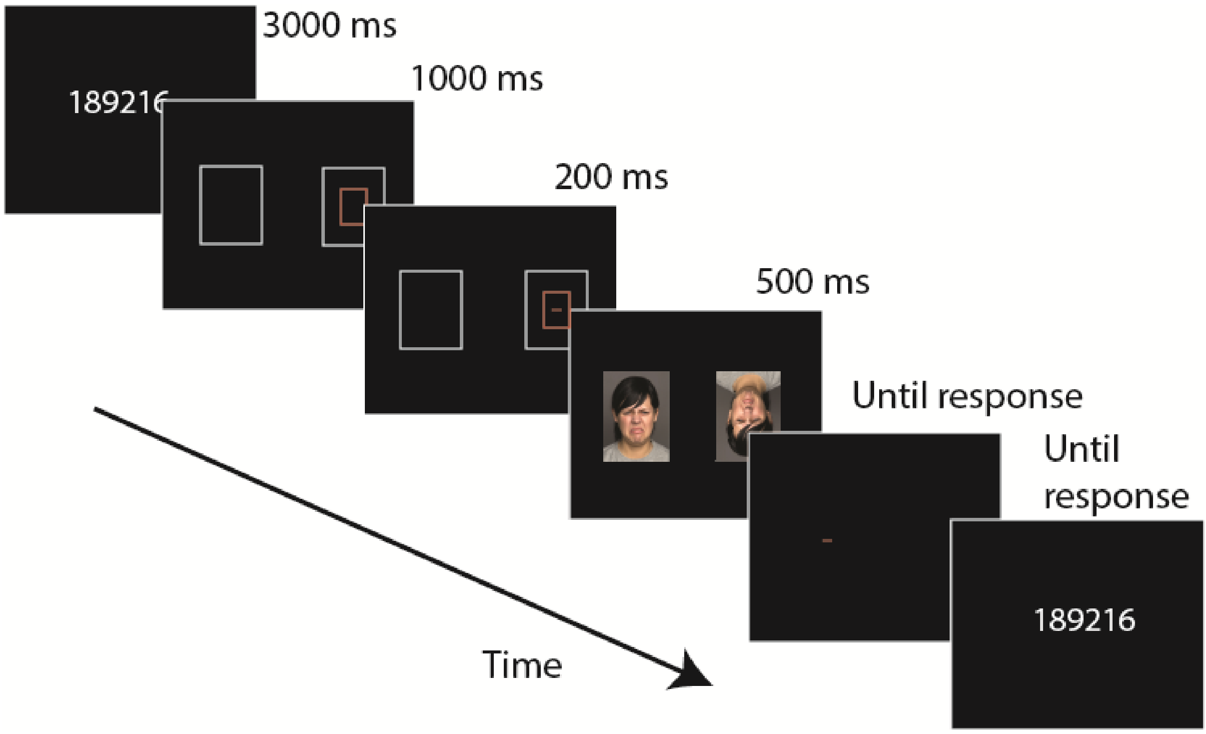

Figure 1. A schematic of an engagement trial under high-load.

An engagement trial was defined as a trial in which the upright face was presented in the opposite location of the preceding cue (for a discussion, see Rudaizky et al., 2014). This is because these trials measure the likelihood that participants will shift their attention toward the upright face. By contrast, for disengagement trials, the upright face was presented in the same location as the preceding cue. Therefore, participants were required to disengage their attention from the upright face to respond to a subsequent probe in the distal location.

Calculation of bias indices. In accordance with the method developed by Grafton and MacLeod (2014) and Rudaizky et al. (2014), engagement bias and disengagement bias indices were calculated. Higher scores for the attentional engagement bias index reflects facilitated attentional orienting toward the disgust expression compared with the neutral expression. The equation is as follows:Engagement bias index = (Cue probe distal to upright negative image in upright negative/inverted image pair: RT for target probes distal to upright negative image minus RT for target probes proximal to upright negative image) minus (Cue probe distal to neutral upright image in neutral upright/inverted image pair: RT for target probes distal to upright neutral image minus RT for target probes proximal to upright neutral image).

Similarly, higher scores for the attentional disengagement bias index reflects greater difficulty disengaging from the disgust expression compared with the neutral expression. The equation is as follows:

Disengagement bias index = (Cue probe proximal to upright negative image in upright negative/inverted image pair: RT for target probe distal to upright negative image minus RT for target probe proximal to upright negative image) minus (Cue probe proximal to upright neutral image in upright neutral/inverted image pair: RT for target probe distal to upright neutral image minus RT for target probe proximal to upright neutral image).

Results

The data from two participants were excluded due to technical failure. A further participants' data were excluded due to responding quicker than 100ms throughout the experiment, indicating random responding. Finally, three participants' data were excluded as their overall RTs were slower than 3.29 SDs from average. Therefore, 94 participants' data were included in further statistical analyses.

The mean accuracies on the probe task was 94.96% (*SD*=3.47) in the no-load condition, 96.89% (*SD*=2.72) in the low-load condition, and 96.08% (*SD*=2.83) in the high-load condition. The mean accuracy on the digit-span task was significantly ($t(93)=7.10$, $p<.001$) higher in the low-load condition (*M*=94.56%, *SD*=4.17) compared with the high-load condition (*M*=89.94%, *SD*=7.79) indicating that, as expected, the six-digit task was more difficult than the one-digit task.

Data from trials in which participants performed incorrectly on the probe task were excluded from analyses because this indicates that participants were not attending in the correct location at the beginning of the trial. In addition, in the low- and high-load conditions, trials in which participants responded incorrectly on the digit task were excluded as the load manipulation may not have been successful on these trials. Further exclusions were made for trials in which RTs were less than 100ms or greater than 2.5 standard deviations above the individual participant's mean RT. Each participants' mean performance was then calculated for each condition. The average percentage of excluded trials was 7.60% for the no-load condition, 13.26% for the low-load condition, and 18.20% for the high-load condition.

Engagement Bias

Since the construct of social fear is a continuous variable in the population (McNeil, 2010), social anxiety was analysed as continuous in this study. Furthermore, since engagement and disengagement biases are separate attentional processes (Grafton & MacLeod, 2014), they were analysed separately. Using the engagement bias index equation, each participant's engagement bias was calculated. To analyse the engagement bias, a repeated-measures ANCOVA was performed with the within-subject factor of load (no, low, and high) and the continuous variable of social anxiety. Mauchley's test indicated that the assumption of sphericity had been violated for load ($\chi^2(2)=15.53$, $p<.001$) and, therefore, degrees of freedom were corrected using the Greenhouse-Geisser estimate of sphericity (ε = .86).

Load was not found to be significant ($F(1.73, 91)=.85$, $p=.416$, $\eta_p^2=.009$), which indicates that the engagement bias index did not alter across the no-load, low-load, and high-load conditions. In addition, the interaction between load and social anxiety was not significant ($F(1.73, 91)=.64$, $p=.507$, $\eta_p^2=.007$). However, a significant *trend effect* was found for the relationship between social anxiety level and the engagement bias index ($F(1, 92)=3.12$, $p=.081$, $\eta_p^2=.033$). Scatterplots revealed that, surprisingly, the engagement bias index *decreased* with increasing levels of social anxiety. To quantify the effect, a median split was conducted to compare participants with low versus high social anxiety. Participants with low social anxiety had a mean engagement bias index of 4.97ms and participants with high social anxiety had a mean engagement bias index of -6.61ms. This indicates that low social anxiety was associated with a slight bias *toward* disgust expressions and high social anxiety was associated with a slight bias *away* from disgust expressions. Raw data are presented in Appendix A.

Post-hoc exploratory analyses. Due to past research indicating that people rapidly habituate to threatening images (Breiter et al., 1996; Staugaard, 2009), it was hypothesised that the threat bias may have diminished over the course of the experiment. To further elucidate the trend engagement effect found in the previous analysis, the data from participants' first block (224 trials) of data were analysed. An ANCOVA was performed with the between-subjects factor of load (no, low, and high) and the continuous predictor variable of social anxiety. The main effect of load was not significant ($F(2, 90)=1.51$, $p=.227$, $\eta_p^2=.032$), confirming that load did not impact engagement toward disgust expressions. However the impact of social anxiety on the engagement bias index was significant (F(1, 90)=4.66, p=.034, η_p^2=.049). Similar to the overall analysis, observation of scatterplots (see Figure 2) indicated that the engagement bias index decreased with higher levels of social anxiety. In addition, a median split indicated that participants with low social anxiety had an engagement bias index of 10.26ms, which suggests that they had a bias toward threat, and participants with high social anxiety had an engagement bias index of -10.50ms, indicating a bias away from threat. Raw data are presented are Appendix B.

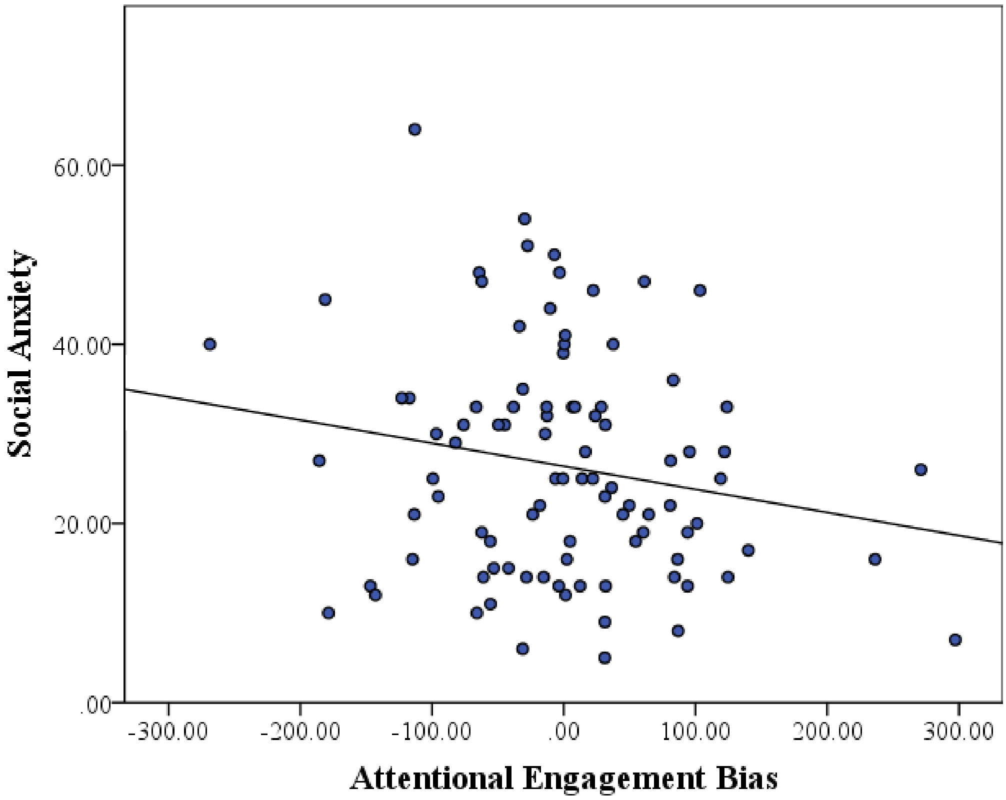

Figure 2. Relationship between social anxiety and attentional engagement toward threat.

Disengagement Bias

To analyse the disengagement bias index, a repeated-measures ANCOVA was performed with the within-subject factor of load (no, low, and high) and the continuous predictor variable of social anxiety. Load was not significant (F(2, 91)=.03, p=.975, $\eta_p^2 \leq$.001), which indicates that the disengagement bias index did not alter across the no-load, low-load, and high-load conditions. In addition, no significant effects were found for social anxiety level (F(2, 91)=.283, p=.596, η_p^2=.003) or the interaction between load and social anxiety (F(2, 91)=.95, p=.387, η_p^2=.010). This indicates that social anxiety was not associated with difficulty disengaging from disgust facial expressions.

A sidenote on these results was that, unexpectedly, participants were faster to respond to a probe presented in the distal location (M=698ms) compared with the proximal location (M=717ms) of the upright image (F(1, 92)=6.06, p=.016, η_p^2=.062). This suggests that participants had already disengaged from the upright image, both for neutral and disgust expressions, when the probe appeared. The implications of this are addressed in the discussion.

Discussion

Despite the proliferation of research exploring attentional biases, the differential roles of bottom-up and top-down attentional mechanisms remain unclear. Using a variation of the dot-probe task, the present project aimed to test whether engagement and disengagement biases toward negative facial expressions for individuals with higher levels of social anxiety are driven by top-down attention. Specifically, the present project employed a WM load task to manipulate the availability of top-down attentional resources to test if this impacted attentional biases toward threat.

Do Socially Anxious Individuals have an Engagement Bias Toward Threat?

Surprisingly this study did *not* find any evidence that individuals with higher social anxiety have an engagement bias toward disgust expressions compared with neutral expressions. In fact, the study found the opposite effect. Although only significant at trend levels (p =.081), the present study found that increasing levels of social anxiety was associated with a decreased engagement bias. In fact, individuals with high social anxiety were faster to respond to probes following neutral expressions compared with the disgust expressions, indicating a bias *away* from threat.

We hypothesised that the effects may have become diluted over the course of the experiment due to habituation to threat. The present study included 224 trials per load condition, which totalled 672 trials per participant. Past research indicates that participants rapidly habituate to emotional faces in the dot-probe task (Staugaard, 2009), which may have accounted for the small effect that was found. To explore this possibility, each participants' first block of trials (totalling 224 trials) were analysed separately. The trend that was found in the previous analysis was now significant (*p*=.034), indicating that participants with lower levels of social anxiety had an engagement bias toward the disgust expressions and participants with high social anxiety had a bias away from the disgust expressions.

These results differ from Grafton and MacLeod's (2016) study, which found that socially anxious individuals had an engagement bias toward negative facial expressions. This is surprising as these two studies aimed to measure the same attentional processes. However, there are some differences in the experimental design, which may account for these opposing results. In Grafton and MacLeod's (2016) study, they paired negative and neutral faces together on each trial. By contrast, the present study was more similar to the design employed by Grafton and MacLeod (2014) and Rudaizky et al. (2014) who presented the neutral and negative images on separate trials. However, whereas Grafton and MacLeod (2014) and Rudaizky et al. (2014) paired the threat and neutral scenes with an abstract image on each trial, the present study paired negative and neutral faces with their inverted face counterpart to control for low level visual properties that may capture attention. Any of these methodological differences, either individually or in concert, may be the reason for the contrasting pattern of results.

The lack of threat engagement bias for high socially anxious individuals found in this study reflects the complex nature of attention. For instance, past research has found enhanced engagement toward threat, delayed disengagement from threat, avoidance of threat, or even no biases at all (see Cisler & Koster, 2010). Furthermore, research has recently emerged suggesting that anxiety is associated with high variability in attending to threat (Zvielli, Bernstein, & Koster, 2015). On a dot-probe task, Zvielli et al. (2015) calculated a trial-level bias score by subtracting temporally contiguous pairs of congruent trials (when the probe was presented in the locus of a threatening image) with incongruous trials (when the probe was presented in the locus of a neutral image). This study found that, compared to healthy controls, spider phobics had greater variability in attentional capture throughout the experiment, sometimes displaying biases toward spider-related material and sometimes displaying biases away from threat. An average bias score across an experiment does not reveal these temporal dynamics. The current bias away from threat could, therefore, reflect the fact that the socially anxious participants tended to avoid the threatening faces for longer (more trials) after initially engaging with the threatening face.

A second possibility is that individuals with high social anxiety were attracted to the threat value of the *inverted* face. Inverted faces were selected as the paired face to control for attentional capture due to low-level perceptual differences across the two presented images. Furthermore, a large body of research indicates that emotion processing of faces is disrupted by inversion as the spatial-relations of the face are not properly processed (de Gelder, Teunisse, & Benson, 1997; Searcy & Bartlett, 1996). However, more recent research indicates that, although inverted faces are processed in a more piecemeal manner, rapid emotion detection can still occur (Arnold & Lipp, 2011). As described previously, the cognitive model of social anxiety posits that individuals with social anxiety are hypervigilant to monitoring their external environment for signs of negative evaluation from others (Rapee & Heimberg, 1997). In the presence of threat, it is possible that this hypervigiliance displayed by socially anxious individuals caused them to monitor the inverted face as well as the upright face. Further research is, therefore, needed to test whether the lack of engagement bias displayed by highly socially anxious individuals is driven by greater temporal variabiliy or due to the choice of inverted face as the paired image.

Do Socially Anxious Individuals have a Disengagement Bias Toward Threat?

The present study found no evidence that socially anxious individuals have a disengagement bias toward disgust expressions. This is consistent with Grafton and MacLeod's (2016) conclusion that social anxiety is associated with unusual engagement toward threat but not difficulty disengaging from threat. However, one potential issue with this conclusion is that the present study found faster RTs in the distal probe position compared with the proximal probe position. This means that on average, when the probe appeared, participants had already disengaged their attention from the position of the target face. It is possible that a briefer presentation time for the faces is needed to capture a delayed disengagement effect as the present study employed a presentation time of 500ms.

A further reason to be hesitant to conclude that socially anxiety is not associated with delayed disengagement is that trait anxiety, which has similar theoretical underpinnings to social anxiety, is associated with delayed disengagement from threat (Grafton & MacLeod, 2014; Rudaizky et al., 2014). For instance, using 500ms and 1000ms presentation times, Rudaizky et al. (2014) paired visual scenes (threatening or neutral) with images of abstract art and found that participants with high trait anxiety had a delayed disengagement bias for threat compared with low trait anxious participants. It is possible that participants may take longer to process complex visual scenes than faces, therefore, taking longer to disengage attention from a visual scene compared with a face. Interestingly, Grafton and MacLeod (2014), who utilised a similar design to Rudaizky et al. (2014), found delayed disengagement from threat for high trait anxious participants at 100ms stimulus durations but not 500ms stimulus durations. Disengagement effects, therefore, may be more robust for short stimulus presentation times. This indicates that, before conclusions about social anxiety and disengagement effects can be made, it is essential for further research to test these effects at durations shorter than 500ms.

The Effect of WM Load on Engagement and Disengagement Biases

In addition to measuring engagement and disengagement threat biases associated with social anxiety, the present study aimed to test whether these were driven by top-down attention. This study found no effect of WM load for both the engagement and disengagement analyses. Unfortunately, since a social anxiety related disengagement bias toward threat was not found, the impact of WM load on such a bias cannot be determined. However, although the engagement effects were unexpected, an engagement bias toward threat was found for low socially anxious individuals and a bias away from threat was found for high socially anxious individuals. These results were unaffected by the load manipulation, indicating that they are bottom-up. This result is in accordance with the traditional view that anxiety is associated with an overactive bottom-up threat detection system (Mogg & Bradley, 1998; Öhman, 2007).

Conclusion and Implications

In sum, the present study indicated that social anxiety is associated with unusual engagement with negative facial expressions. Specifically, participants with high social anxiety had a slight bias away from threat and participants with low social anxiety had a bias toward threat. This was unaffected by WM load, which indicates that engagement with threat requires few attentional resources and is, therefore, largely driven by bottom-up attention. Social anxiety was not found to be associated with differences in disengagement from threat. Due to mixed findings in the literature, further research is now needed to clarify the conditions under which high social anxiety is associated with biases either *toward* or *away* from threat. In addition, as discussed previously, further research using shorter presentation times is needed before concluding that social anxiety is not associated with delayed disengagement from threat.

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Appendix A

Data Summary

Data for the no-load, low-load and high-load conditions are presented in Table A1, Table A2, and Table A3, respectively. In addition, attentional engagement bias index and disengagement bias index data are presented in Table A4. Low and high social anxiety groups were calculated using a median split.

Table A1

Mean response times (ms) obtained in the no-load condition for low and high social anxiety groups

Cue locus	Image valence	Target probe locus	Low social anxiety *M (SD)*	High social anxiety *M (SD)*
Distal	Negative	Distal	723.24 (140.27)	688.49 (151.48)
(*attentional engagement trials*)		Proximal	696.82 (140.87)	656.02 (155.37)
	Neutral	Distal	731.97 (147.31)	692.72 (157.55)
		Proximal	691.95 (159.26)	655.33 (173.96)
Proximal	Negative	Distal	711.45 (144.62)	684.94 (163.66)
(*attentional disengagement trials*)		Proximal	743.72 (151.00)	700.86 (174.18)
	Neutral	Distal	696.83 (139.50)	670.15 (160.89)
		Proximal	724.91 (159.45)	685.95 (151.10)

Table A2

Mean response times (ms) obtained in the low-load condition for low and high social anxiety groups

Cue locus	Image valence	Target probe locus	Low social anxiety *M (SD)*	High social anxiety *M (SD)*
Distal	Negative	Distal	780.42 (167.80)	721.12 (175.19)
(*attentional engagement trials*)		Proximal	760.50 (168.82)	712.69 (207.34)
	Neutral	Distal	786.83 (179.25)	755.62 (216.03)
		Proximal	776.43 (193.29)	724.63 (183.32)
Proximal	Negative	Distal	773.63 (181.00)	724.86 (191.63)
(*attentional disengagement trials*)		Proximal	792.65 (195.46)	725.72 (169.50)
	Neutral	Distal	756.25 (165.45)	720.51 (186.21)
		Proximal	785.41 (170.95)	744.75 (184.28)

Table A3

Mean response times (ms) obtained in the high-load condition for low and high social anxiety groups

Cue locus	**Image valence**	**Target probe locus**	**Low social anxiety *M (SD)***	**High social anxiety *M (SD)***
Distal (*attentional engagement trials)*	Negative	Distal	712.25 (148.15)	649.01 (108.89)
		Proximal	671.27 (144.95)	624.89 (112.56)
	Neutral	Distal	697.32 (150.32)	645.99 (108.80)
		Proximal	675.31 (143.51)	629.50 (103.89)
Proximal (*attentional disengagement trials)*	Negative	Distal	680.27 (157.41)	634.69 (119.23)
		Proximal	708.97 (151.39)	655.56 (118.55)
	Neutral	Distal	674.31 (134.42)	648.35 (130.86)
		Proximal	698.97 (153.45)	642.09 (126.56)

Table A4

Means and standard deviations of attentional bias index scores for the three load conditions

	Load condition	**Engagement bias**	**Disengagement bias**
Low social anxiety *M (SD*)	No load	-13.60 (94.07)	-4.19 (93.60)
	Low load	9.52 (112.44)	10.15 (80.05)
	High load	18.98 (100.65)	-4.05 (124.66)
High social anxiety *M (SD)*	No load	-4.91 (76.92)	-0.12 (75.77)
	Low load	-22.56 (115.26)	23.38 (90.77)
	High load	7.63 (73.38)	-27.12 (93.21)

Appendix B

Data Summary: First Block of Trials

Data for the no-load, low-load and high-load conditions for participants' *first block* of trials (224 trials) are presented in Table B1, Table B2, and Table B3, respectively. In addition, attentional engagement bias index and disengagement bias index data are presented in Table A4. Low and high social anxiety groups were calculated using a median split.

Table B1

Mean response times (ms) obtained in the no-load condition for low and high social anxiety groups for block one of trials

Cue locus	Image valence	Target probe locus	Low social anxiety *M (SD)*	High social anxiety *M (SD)*
Distal	Negative	Distal	710.058(134.71)	799.34 (151.82)
(*attentional engagement trials)*		Proximal	702.54 (163.45)	752.71 (149.92)
	Neutral	Distal	722.72 (148.28)	809.19 (162.17)
		Proximal	683.19 (156.20)	778.05 (187.63)
Proximal	Negative	Distal	722.66 (168.05)	799.73 (152.24)
(*attentional disengagement trials)*		Proximal	729.73 (140.94)	822.73 (203.16)
	Neutral	Distal	707.75 (162.00)	780.81 (150.22)
		Proximal	694.61 (118.85)	785.94 (158.89)

Table B2

Mean response times (ms) obtained in the low-load condition for low and high social anxiety groups for block one of trials

Cue locus	Image valence	Target probe locus	Low social anxiety *M (SD)*	High social anxiety *M (SD)*
Distal	Negative	Distal	854.28 (162.58)	725.13 (140.48)
(*attentional engagement trials)*		Proximal	824.28 (172.89)	740.04 (175.22)
	Neutral	Distal	839.20 (172.10)	753.05 (174.54)
		Proximal	834.99 (197.25)	726.63 (151.73)
Proximal	Negative	Distal	857.06 (179.15)	733.91 (151.94)
(*attentional disengagement trials)*		Proximal	861.56 (156.94)	741.99 (158.85)
	Neutral	Distal	831.80 (179.33)	727.39(136.719)
		Proximal	852.97 (167.62)	736.03 (163.06)

Table A3

Mean response times (ms) obtained in the high-load condition for low and high social anxiety groups for block one of trials

Cue locus	Image valence	Target probe locus	Low social anxiety *M (SD)*	High social anxiety *M (SD)*
Distal (*attentional engagement trials)*	Negative	Distal	795.51 (94.36)	654.04 (83.84)
		Proximal	729.99 (106.39)	645.42 (108.40)
	Neutral	Distal	783.62 (112.04)	658.37 (86.81)
		Proximal	767.76 (95.05)	643.53 (104.24)
Proximal (*attentional disengagement trials)*	Negative	Distal	756.83 (124.60)	652.17 (108.39)
		Proximal	784.69 (108.30)	678.97 (91.45)
	Neutral	Distal	717.69 (89.50)	674.93 (115.75)
		Proximal	785.98 (145.19)	660.09 (98.46)

Table B4

Means and standard deviations of attentional bias index scores for the three load conditions for block one of trials

	Load condition	Engagement bias	Disengagement bias
Low social anxiety *M (SD)*	No load	-32.01 (60.84)	-20.21 (66.91)
	Low load	25.80 (107.87)	16.68 (87.76)
	High load	49.66 (92.51)	40.44 (160.04)
High social anxiety *M (SD)*	No load	-15.49 (100.77)	-17.88 (81.02)
	Low load	-41.34 (99.16)	0.56 (105.43)
	High load	-6.22 (69.05)	-41.65 (69.21)

Chapter Eight. What is Top-Down About Seeing Enemies? Social Anxiety and Attention to Threat

Chapter Overview

Chapter Seven tested the relative contributions of top-down attention and bottom-up attention to biases in threat for individuals with high levels of social anxiety. Surprisingly, however, this study found that participants with high levels of social anxiety had a bias away from threat and individuals with low social anxiety had a bias toward threat. These biases were unaffected by the WM load manipulation, which provides initial evidence that the threat bias may be bottom-up in nature. However, there are some methodological factors, which are further explored in Chapter Eight, that may account for these unusual findings. Before conclusions can be drawn from the results of Chapter Seven, we determined that further research was needed. The purpose of Chapter Eight, therefore, was to overcome the methodological limitations of Chapter Seven and, once again, test the relative contributions of top-down and bottom-up attention to threat detection.

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Author Contributions

- **Delchau** proposed the project.
- **Delchau** designed the experiment with contributions from Goodhew, Christensen, and O'Kearney.
- **Delchau** coded the computer task.
- **Delchau** collected the data.
- **Delchau** analyzed the data, with advice from Goodhew.

- **Delchau** and all other authors contributed to discussions surrounding interpretation of the data.
- **Delchau** produced the tables and figures.
- **Delchau** wrote the manuscript, with editing provided by Goodhew, Christensen, and O'Kearney.
- After reviews were received from *Attention, Perception and Psychophysics*, **Delchau** refined the manuscript in response to the reviewers' comments, with editing provided by Goodhew, Christensen, and O'Kearney.

What is top-down about seeing enemies? Social anxiety and attention to threat

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Abstract

An attentional bias to threat is an important maintaining and possibly aetiological factor for social anxiety. Despite this, little is known about the underlying mechanisms of threat biases, such as the relative contributions of top-down and bottom-up attention. In order to measure attentional bias toward threat, the current study employed a variation of the dot-probe task in which participants' (*N* = 103) attention was initially cued to the left or right side of the screen before an angry face paired with a neutral face was displayed, and subsequently participants responded to a probe in the locus of one of the faces. This design provides separate measures of engagement with and disengagement from threat. In addition, in order to manipulate the availability of top-down attentional resources, participants completed this task under no, low (simple arithmetic task), and high (difficult arithmetic task) working memory load. Higher levels of social anxiety were found to be associated with increased engagement with threat under no-load, whereas this effect was eliminated under low- and high-load conditions. Moreover, social anxiety was not associated with delayed disengagement from threat. These results highlight the critical role of top-down attention for engaging attention with threat.

Keywords: selective attention, spatial attention, working memory load, social anxiety, dot-probe, threat bias; top-down; bottom-up.

What is top-down about seeing enemies? Social anxiety and attention to threat

Faces convey critical social information. It is, therefore, unsurprising that social anxiety, which is characterised by a fear of being judged and scrutinised by others, is associated with an *attentional bias* toward threatening facial expressions (e.g., anger and disgust). For example, Rapee and Heimberg (1997) hypothesised that socially anxious individuals vigilantly monitor their external environment for signs of negative evaluation from others. This results in a reinforcing loop of anxiety, whereby socially anxious individuals are more likely to notice signs of disapproval from others, which further increases their anxiety, causing them to be more hypervigilant of criticism. This model is supported by research findings that socially anxious individuals show biased attention toward photos of faces depicting angry, hostile, and disgust expressions compared with neutral facial expressions (Mogg, Philippot, & Bradley, 2004; Pishyar, Harris, & Menzies, 2004), and that correcting this bias can reduce symptoms of anxiety (Liu, Li, Han, & Liu, 2017). Given the strong link between attention and social anxiety, it is imperative that research is conducted to improve our understanding of the mechanisms underlying biased attention to threat. The purpose of this study, therefore, was to apply a key theoretical framework of attention to understand the nature of biased attention to threat for socially anxious individuals.

A central tenet of the current study is that taxonomies of normative attention may guide our understanding of anxiety-related attention to threat. In this vein, it is commonly accepted that at any given moment, there is typically far more information available in visual scenes than the human brain is capable of fully processing. The attentional system, which acts like a filter, is crucial for allowing us to process and interact with our visual world. That is, the attentional system selects important and relevant information for further processing at the expense of other information (Desimone & Duncan, 1995; Kastner & Pinsk, 2004). The manner in which selective attention takes place can be subdivided into top-down and bottom-up attention. *Top-down* attention refers to the voluntary allocation of attention toward particular objects, features, or spatial locations based on one's current goals. For example, when searching for your child on a busy beach, if you know that he or she is wearing a blue swimsuit, you can more efficiently search to find your child by selectively attending to blue objects. *Bottom-up* (also known as automatic) attention, by contrast, is an involuntary, rapid, and inflexible process that selects visual information based on the salience of the stimulus features (e.g., automatically orienting to a seagull that swoops down in front of you).

A general question emerging from the anxiety-attention literature has been whether threat detection relies on bottom-up or top-down attention. The argument that attention to threat is driven by bottom-up mechanisms comes from an evolutionary perspective, which emphasises the adaptive purpose of attending to threat (Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010; Lang, Bradley, & Cuthbert, 1997; LeDoux, 1996; LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). This argument contends that survival can depend on the rapid detection of threatening stimuli, which might cause an individual harm (e.g., predators, dangerous environments, and social signs of anger from other people). The bottom-up attentional system is ideally suited to the purpose of triaging the processing of such stimuli, since it is more rapid than the top-down attentional system (Busse, Katzner, & Treue, 2008), and a timely response to threat is of the essence. Furthermore, its operation is automatic and, therefore, less dependent on the individual's intentions or competing goals at that point in time. In other words, it is a more fail-safe system.

The bottom-up system typically operates at the level of basic stimulus features (e.g., colour, shape, orientation, and motion). From this point of view, it would be difficult for the system to be tuned to a more complex property, such as "threat", which can take varied visual forms and is undoubtedly multifactorial in nature. However, consistent with the notion of a bottom-up attentional system tuned to features of threat, a body of research suggests that such a bias is driven by specific low-level perceptual features associated with prototypical threatening stimuli (LoBue, 2014; LoBue & DeLoache, 2011; LoBue & Larson, 2010). One example of this is a bias toward curvilinear shapes, which are reminiscent of the shape of a snake or spider's legs. In a visual search task, LoBue (2014) demonstrated that participants have a bias toward curvilinear shapes compared with rectangular shapes. Furthermore, illustrating the association between anxiety and threat detection, LoBue also showed that fear-inducing film clips facilitate the detection of curvilinear shapes. Furthermore, children display biases toward downward "V" and triangle shapes, which are similar to the shape of angry eyebrows (LoBue & Larson, 2010). This adds further support to the notion that threat detection may be an evolved, automatic system.

However, an accumulating body of research indicates that threat detection may be modulated by, or even driven by, top-down attention and is *not* purely the product of bottom-up attention. Conceptually, this means that rather than an automatic (possibly even innate) bias toward threat, that is triggered as reflexively as orienting toward a bright flash of light, the bias toward threat might reflect top-down attention. Top-down attention can work at a more conceptual level, such as the level of semantic categories (Goodhew, Kendall, Ferber, & Pratt, 2014; Most, 2013; Wyble, Folk, & Potter, 2013), which could arguably include the label 'threat'. The operation of top-down attention is more volitional, flexible, and context-specific than bottom-up biases. Thus, if the bias toward threat in socially anxious individuals occurs via a top-down attentional route, it should be susceptible to a number of contextual factors, such as the individual's goals. In contrast, if the bias towards threat is a bottom-up process, it should be more invariant to these influences.

In an attempt to disentangle whether the attentional bias predominately operates via a top-down or a bottom-up attentional system, previous research has utilised working memory

(WM) load tasks. WM is a limited-capacity system, which, in the face of continued processing and distraction, is responsible for the active maintenance of information (Conway et al., 2005). More specifically, WM functions include the storage and rehearsal of information and executive functions, with tasks tapping these functions including counting, operation span, and reading span (Conway et al., 2005). Indeed, recent researchers have argued that WM is indistinguishable from cognitive control (i.e., top-down attention) (Qi et al., 2014), as the two functions overlap in neural activity (e.g., Bunge, Ochsner, Desmond, Glover, & Gabrieli, 2001; Kondo, Osaka, & Osaka, 2004). Tasks requiring bottom-up attention are unaffected by WM load (Jonides, 1981), whereas WM, which is essential for keeping goals in mind, affects tasks that require top-down attention (de Fockert, Rees, Frith, & Lavie, 2001; Downing, 2000). A logical way to test if an attentional task requires top-down resources is to measure if attention toward threat is altered by the addition of a WM load. Theoretically, when the demands of the WM task increase, the available resources for the second task decrease (Sarampalis, Kalluri, Edwards, & Hafter, 2009; Tun, McCoy, & Wingfield, 2009). The extent to which performance on the secondary task decreases provides clues as to the role of WM demanded by the primary task (Kerr, 1973). Thus, if an attentional bias toward threat is unaffected by a WM load, it suggests that the task requires few top-down attentional resources and is predominantly driven by bottom-up attention. However, if an attentional bias is attenuated under high-load, it indicates that the bias is driven significantly by top-down attention (note that the predictions of WM load and perceptual load differ; see, Lavie, 2005).

Van Dillen and Koole (2009) tested this by using a gender-naming task with centrally-presented happy and angry faces. They found that angry faces resulted in slower gender-naming, compared with happy faces, under low-load but not high-load. This indicates that participants processed the emotion of the faces only when spare attentional resources were available, and the threat bias required top-down attention. Although this is an important finding, this research only tested attention to centrally-presented faces and did not test the association with anxiety. However, shifts of attention across space are crucial to the conceptualisation of the threat biases for socially anxious individuals, because in everyday life there is competition between visual stimuli and threat-related stimuli and these stimuli do not always appear in the current locus of attention. For example, to explain why someone with social anxiety attends to threatening facial expressions but not encouraging expressions from the audience when presenting a speech requires understanding *shifts* in spatial attention toward and away from facial expressions.

The relationship between social anxiety and spatial shifts of attention towards threat was assessed by Judah, Grant, Lechner, and Mills (2013). Two groups of participants were included: a socially anxious group and a non-anxious control group. These researchers employed a dot-probe task and presented participants with images of happy, disgust, and neutral facial expressions under no-, low-, and high-WM-load conditions. In this design, two faces were presented on each trial; one to the left and one to the right of fixation. A probe (e.g., a letter) followed in the location of one of the faces and participants reported its identity. Faster reaction times (RTs) to the probe following a threatening facial expression compared with RTs to a probe following a neutral facial expression indicated that participants were attending to the threatening face. This difference in RT reflected a threat bias.

Judah et al. (2013) found that the group with social anxiety had a *reduced* bias to the disgust expressions under no-load and a *greater* bias toward the disgust expressions under high-load, compared with the control group. Since these researchers employed long presentation times for the faces (1000ms), they argued that this reflected avoidance of threat under no-load and delayed disengagement from threat under high-load.

In other words, when the social anxiety group had attentional resources to spare (no-load condition), they could volitionally shift their attention to avoid the threatening face. However, when these resources were consumed with the WM load task, they were not able to instantiate this disengagement. One potential issue with this design is that it assumes that all participants initially shifted their attention toward the threatening stimulus to an equal degree. If, however, social anxiety impacted on participants' initial engagement with threat, then subsequent measures of disengagement and avoidance are undermined. It is, therefore, essential to measure engagement and disengagement biases separately.

Employing a paradigm developed by Grafton and MacLeod (2014) and Rudaizky, Basanovic, and MacLeod (2014), this issue was mitigated by Boal, Christensen, and Goodhew (2018). Separately measuring attentional engagement and disengagement biases, these researchers tested if the threat bias associated with social anxiety is driven by top-down or bottom-up attention. On each trial, participants were initially presented with a cue (a small red line oriented horizontally or vertically). This cue was presented either on the left or right side of the screen and, accordingly, secured participants' attention in the same location or opposite location to the target image. Participants then viewed a target image (an upright neutral or disgust face) paired with its inverted counterpart. A probe (a small red line oriented horizontally or vertically) was then presented in the locus of one of the images, and participants reported whether it matched the orientation of the initial cue or was different. A *disengagement trial* was defined as a trial in which the target face was presented in the *same* location as the preceding cue. On half of these trials, the probe was then presented in the same location as the target face and on half of the trials the probe was presented in the opposite location. The disengagement condition measured the speed to which participants disengaged their attention from the target face to respond to a subsequent probe presented in the opposite location compared with when they were required to respond to a probe in the same location as the target face. Therefore, slower disengagement of attention on the threat-target trials compared with the neutral-target trials indicates a disengagement bias for threat. An *engagement trial,* by contrast, was defined as a trial in which the target face was presented in the *opposite* location to the preceding cue. On half of these trials, the probe was then presented in the same location as the target face and on half of the trials the probe was presented in the opposite location. The engagement trials measured the speed to which participants shifted their attention away from the inverted face toward the target face. Faster RTs to the probe following the target face compared with the probe following the inverted face for threatening-target trials compared with neutral-target trials indicated a threat bias.

To test if attentional biases to threat requires top-down attentional resources, the task was performed under three WM load conditions: no-load, low-load (one-digit memory task), and high-load (six-digit memory task). Surprisingly, these researchers found that high social anxiety was associated with an engagement bias away from threat whereas low social anxiety was associated with a bias toward threat. The disengagement bias was not related to social anxiety. Finally, since these effects were not significantly affected by the WM load manipulation, it was concluded that engagement with threatening facial expressions had minimal contributions from top-down mechanisms.

The present study aimed to extend on the research of Boal et al. (2018) by overcoming three limitations of their study. Firstly, the study employed inverted faces as control images (rather than abstract art images, which were used by Grafton and Macleod (2014) and Rudaizky et al. (2014)). This approach assumes that inversion disrupts the emotion processing of faces, which was predicated on the basis that inversion substantially impairs configural processing of faces (de Gelder, Teunisse, & Benson, 1997; Searcy & Bartlett, 1996). However, other research challenges this view, finding that rapid emotion detection can occur for inverted faces (Arnold & Lipp, 2011). Although Boal and colleague's finding of reduced engagement with threatening faces may have reflected attentional avoidance (see Cisler & Koster, 2010), it may also be due to differences in attending to the inverted face. For instance, it is possible that socially anxious participants, due to hypervigilance to threat, may have detected the threatening expressions contained in the inverted disgust faces and, therefore, readily shifted toward them. This could account for what appeared to be an attentional bias away from (upright) threat observed by Boal et al. (2018). To overcome this issue, the present study directly paired negative and neutral expressions on each trial rather than employing inverted faces (see Grafton & MacLeod, 2016, for a similar approach to selecting distractor images).

Secondly, the present study changed the presentation time of the images from 500ms to 200ms. Although 500ms is a commonly used presentation time in the dot-probe literature, it allows for participants to make multiple covert and/or overt shifts of attention while the image is being presented. Therefore, initial shifts of attention are confounded with later attentional stages (e.g., avoidance). The present study displayed the faces for 200ms to minimise the occurrence of multiple shifts of attention.

The third issue addressed was the complexity of the WM task. The present study employed an arithmetic task rather than memorising digit strings, as was employed in Boal et al. (2018). It is possible that this manipulation had a limited impact on performance because it did not comprehensively exhaust WM resources. The Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV) manual, describes Digit Span Forwards as a test involving "attention, encoding and auditory processing" (Wechsler, 2008, *p*. 15). Thus, the digit span task in Boal and colleagues' study may be better conceptualised as measuring attention and short-term memory rather than WM. Arithmetic, by contrast, has been found to involve all components of WM (DeStefano & LeFevre, 2004).

Present Study

In sum, the aim of the present study was to determine whether engagement and disengagement of attention to threat for individuals with social anxiety is largely driven by top-down or bottom-up attention. To measure attentional biases, the present study employed a dot-probe task in which participants viewed a pair of faces (one angry and one neutral) on each trial. RT to a probe, which was presented either in the location of the preceding angry or neutral face on each trial, was measured. Cueing scores were calculated for the engagement and disengagement trials separately and were compared under three WM load conditions: no-load, low-load, and high-load. The addition of the WM load was designed to test whether attention toward threat requires top-down or bottom-up attention.

Based on Grafton and MacLeod's (2016) findings, under no- and low-load, it was expected that higher social anxiety would be associated with an attentional engagement bias toward the angry faces. If the engagement bias is largely driven by bottom-up attention, this bias would be unaffected by the load manipulation[3]. However, if top-down attentional resources are required for participants to shift toward the angry faces, the engagement bias will reduce in the high-load condition. Finally, the study also planned to clarify whether social anxiety is associated with delayed attentional disengagement for short stimulus presentation times and, if it is, whether it is affected by WM load.

[3] An alternative prediction derives from load theory (Lavie, 2005). Load theory suggests that distractibility increases with increasing cognitive load. According to this theory, the attentional bias toward threat in individuals high in social anxiety should actually increase as load increases. Note, however, that we did not observe this pattern of results.

Method

Participants and Design

One hundred-and-three participants (75 female and 28 male) were recruited from the Australian National University via online advertisement and the university electronic sign-up system. The sample size was chosen so as to be able to detect an effect size *f* of 0.23 ($\eta_p^2 = .05$). This effect size was selected since Grafton and MacLeod (2016) reported an effect size of $\eta_p^2 = .05$ for the interaction between social anxiety and the engagement bias. Using GPower calculations[4] (ANOVA: repeated measures, between factors) with power of 0.8 and an effect size *f* of 0.23, the recommended sample size was 90. Therefore, the sample size of 103 was deemed sufficient (so as to account for some exclusions in data, which were predicted to occur; note that, after exclusions, 91 participants were included in the final analyses). Restrictions were that participants were Caucasian, aged 18-30 years, with normal vision or corrected-to-normal vision. Participants' ages ranged from 18 to 30 years ($M = 19.74$, $SD = 2.32$), and eight participants were left-handed. Participants were offered course credit (if eligible) or $10 cash (AUD).

Experimental Stimuli and Apparatus

This experiment was conducted in a dimly lit room. Viewing distance was set with a chinrest at 44cm and a liquid crystal display monitor running at a 60Hz refresh rate was used to display the stimuli. Stimuli were programmed in Matlab using the Psychophysics Toolbox (Brainard, 1997). The background was set to black and the arithmetic questions were presented in size 18 white, Helvetica font. Images of faces were taken from the NimStim

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[4] Although the GPower analysis did not include the covariate of social anxiety, this analysis with one two-level between-subjects factor and a six-level repeated-measures factor was deemed the closest approximation to this study's design. Since designing the study, it has come to our attention that G*Power does not in fact allow for the computation of power for designs with more than one repeated-measures factor, as was present here. When we specify six measurements G*Power assumes that these all reflect levels of one variable (6x1), rather than a 2x3 factorial design. For future research we plan to use the superior newly available calculators which permit these sorts of common experimental designs, in addition to permitting for correction for publication bias (Anderson, Kelley, & Maxwell, 2017). However, since G*Power was used this is what is reported here.

database (Tottenham et al., 2009). The use of this database in this area of research is common (e.g., Alon, Arad, Pine, & Bar-Haim, 2019; Dima, Perry, Messaritaki, Zhang, & Singh, 2018; Wieckowski, Capriola-Hall, Elias, Ollendick & White, 2019; White, Capriola-Hall, Wieckowski, & Ollendick, 2019). To limit variability in responding to faces due to race, the images selected were Caucasian faces and participants were Caucasian (based on self-report). Caucasian images were employed to control for the cross-race effect in which other-race faces may be processed differently to faces of one's own race (for a review, see Young, Hugenberg, Bernstein, & Sacco, 2012). Furthermore, closed-mouth neutral and angry expressions were selected to reduce bottom-up capture effects from teeth visibility (Horstmann, Lipp, & Becker, 2012). Low-level differences were minimised by ensuring that the two face images presented on each trial were as similar as possible in all respect except their emotional expression. Several faces that met the above criterion were not included, due to issues intrinsic to the image set. One image was the incorrect size (model 1), one had confounding facial hair (model 31), and one did not have the full-range of images available (model 27). Therefore 22 models (7 females and 15 males) were included, each with three associated images of neutral and angry expressions. Although Boal et al. (2018) employed disgust expressions, the current study employed angry expressions because a greater number of closed-mouth angry faces were available in the NimStim database compared with closed-mouth disgust faces. Anger is a form of social threat, and therefore theoretically individuals with high levels of social anxiety should be preferentially sensitive to angry faces relative to neutral faces. Furthermore, previous research demonstrates empirically that socially anxious individuals display the same attentional bias towards angry and disgust expressions (Grafton & MacLeod, 2016). During the experiment, each image subtended approximately 7.60° x 9.76° of visual angle, with a gap of 7.11° of visual angle between the two presented images.

Questionnaires

Symptoms of psychopathology were measured using two questionnaires. Firstly, to assess social anxiety, the Liebowitz Social Anxiety Scale (LSAS: Liebowitz, 1987) was employed in its self-report form. For each of the 24-items, participants are asked to rate both their fear and avoidance on a 4-point Likert-type scale. Fear is rated from 0 (none) to 3 (severe) and avoidance rated from 0 (never) to 3 (usually, 68%-100%). A total score can be calculated by summing scores from both the fear and avoidance scales, yielding a maximum score of 144. This measure was selected as it has good psychometric properties (Baker, Heinrichs, Kim, & Hofmann, 2002; Fresco et al., 2001; Levin, Marom, Gur, Wechter, & Hermesh, 2002; Oakman, Van Ameringen, Mancini, & Farvolden, 2003; Rytwinski et al., 2009) and is brief and easily administered. In a large university study, Caballo, Salazar, Irurtia, Arias, and Nobre (2013) reported that males had a mean score on the LSAS-Self Report (LSAS-SR) of 42.19 and females had a mean score of 45.73. The current study had higher scores than those of Caballo et al. (2013), as total LSAS-SR scores ranged from 11 to 104 (*M* = 55.41, *SD* = 22.87), with the subscale of Fear ranging from 5 to 56 (*M* = 28.57, *SD* = 11.68) and Avoidance ranging from 4 to 54 (*M* = 26.91, *SD* = 12.16).

Secondly, generalised anxiety and depression were assessed with the Depression Anxiety Stress Scale-21 (DASS-21), which is a short form of Lovibond and Lovibond’s (2005) 42-item self-report measure (DASS). Although the DASS-21 results were not primary measures of interest, these data were collected to provide more complete demographic information of the participants. The DASS-21 is a 21-item measure, in which participants rate the degree to which symptoms applied to them over the past week. Ratings are made on a 4-point Likert scale from (never) to 3 (almost always). This measure provides separate scores for depression, anxiety and stress, each ranging from 0 to 42. The DASS-21 was chosen because it has good convergent, discriminant, and construct validity (Crawford & Henry, 2003; Henry & Crawford, 2005; Lovibond & Lovibond, 1995) and reliability (Antony, Bieling, Cox, Enns, & Swinson, 1998; Brown, Chorpita, Korotitsch, & Barlow, 1997; Crawford & Henry, 2003; Lovibond & Lovibond, 1995). The depression scores ranged from 0 to 38 (M = 10.17, SD = 8.97), anxiety ranged from 0 to 38 (M = 9.59, SD = 8.17), and stress ranged from 0 to 38 (M = 15.30, SD = 8.82).

Procedure

Participants completed the consent form and demographic questions, the computer task, and then the questionnaires. The computer task consisted of three blocks of trials (no-load, low-load, and high-load), order counterbalanced across participants. Each block consisted of an initial 12 practice trials and then a further 112 experimental trials; 56 of those trials consisted of engagement trials and 56 were disengagement trials (randomly intermixed).

On each trial, initially a blank screen was presented for 1000ms. Next, two white rectangular outlines, one to the left and one to the right of fixation, were presented for 1000ms. These rectangular outlines subtended 7.6° x 9.8° of visual angle and the width of the lines subtended approximately 0.09° and remained visible while the cue was presented. A smaller red rectangle, subtending 1.9° x 2.4°, was also presented inside one of the white rectangles to indicate the location of the to-be-presented cue. The cue (a small red line) was then presented within the box for 200ms. This cue could be oriented horizontally or vertically and subtended a visual angle of 0.5° x 0.1°. The presentation of the cue on the left and right side of the screen were randomised with equal probability of it appearing in each location.

After these stimuli disappeared, two images of faces were presented for 200ms, one to the left and one to the right of fixation, such that they occupied the locations that the white rectangles previously occupied. On each trial, one face was angry and one was neutral and the two expressions were from the same model. In addition, an equal proportion of female and male faces were presented in each condition. After these faces offset, a probe (a small red line) oriented horizontally or vertically, which was identical in appearance to the cue, was then presented in the locus of one of the faces and was oriented horizontally or vertically. The presentations of the cue and probe as horizontal or vertical were each randomised throughout the experiment. Moreover, for both the engagement and disengagement conditions, the probe appeared behind the angry face on 50% of the trials and behind the neutral face on 50% of the trials (randomly intermixed). Participants made a keyboard press to report whether the orientation of the probe matched the orientation of the cue as quickly and accurately as possible. RTs were measured as the time between onset of the probe and the participants' key press.

The low- and high-load conditions also included a WM load that sandwiched the dot-probe task. On the low-load and high-load trials, after the initial presentation of the blank screen for 1000ms, an additional arithmetic task was then presented. At the beginning of each trial, an arithmetic question was presented centrally for 2500ms. In the low-load condition, the question followed the format "A + B" (simple question) and, in the high-load condition, the question followed the format "A+B-C+D" (difficult question) (where A, B, C, and D consisted of randomly generated whole numbers ranging from 1-10, with a restriction that the answer could only be a positive integer). At the end of each trial, after participants responded to the probe, the words "Even or Odd" was presented centrally. Participants then made a key press to indicate whether the answer to the arithmetic question was an even ("z") or odd number ("/") (see Figure 1).

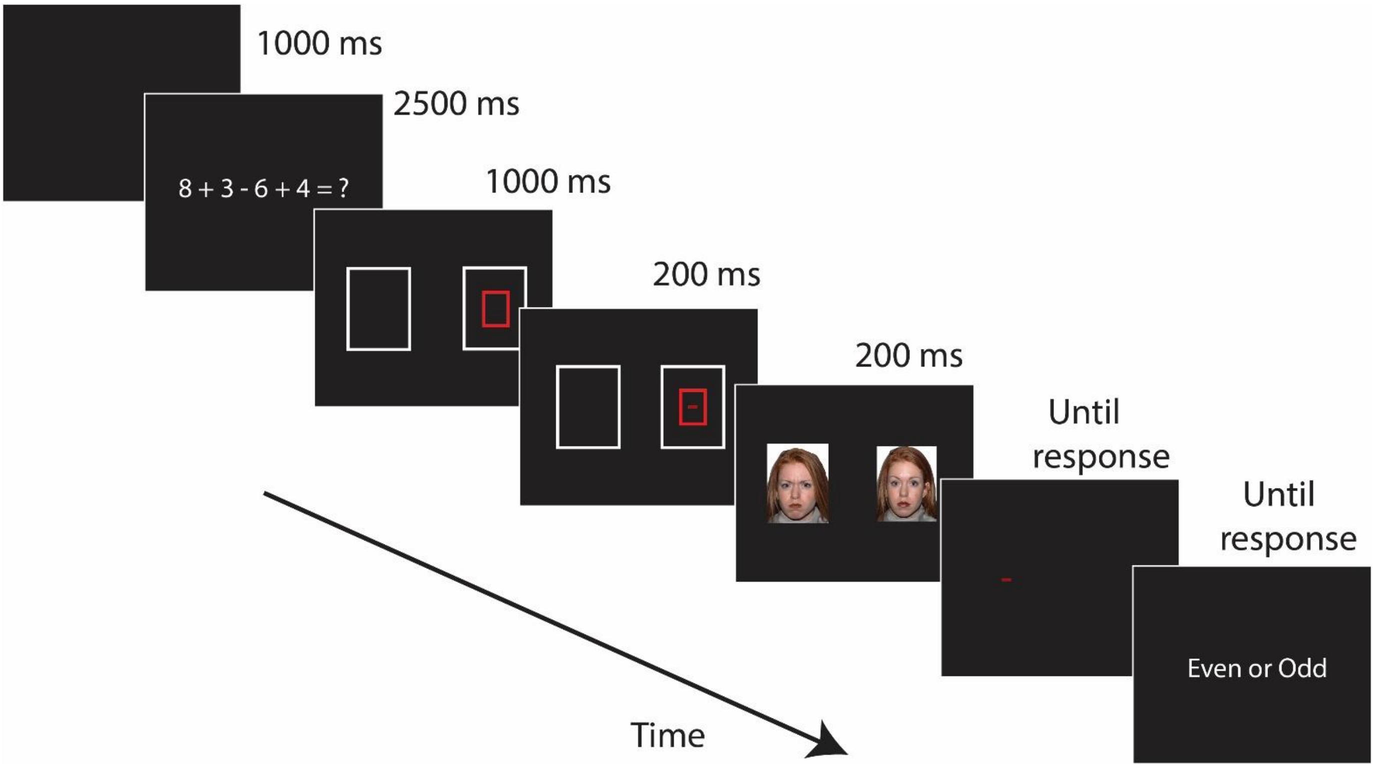

Figure 1. A schematic of an engagement trial under high-load.

The presentation time for the arithmetic question was selected based on pilot testing. The pilot testing sample consisted of 10 participants aged 18-30 years with normal vision or vision corrected with glasses. The mean age was 23.7 years (*SD* = 3.6), 8 participants were female and 2 were male, and all were right-handed. During pilot testing, participants completed a 20-trial block of "simple questions" and a 20-trial block of "difficult questions" and were asked to make keyboard presses to respond to whether the question was an even number or an odd number. For the simple question block, mean accuracy was 95.3% (*SD* = 6.8%) and RTs were 1351.2ms (*SD* = 311.9ms). By comparison, for the difficult question block, mean accuracy was 92.9% (*SD* = 5.3%) and mean RTs were 5526.2ms (*SD* = 1479.0ms). These findings confirmed that participants, on average, would not be able to solve the difficult arithmetic question prior to the faces being presented in the high-load arithmetic condition. Therefore, participants' WM resources would be consumed during face presentation.

Planned calculations. In accordance with Grafton and Macleod's (2016) method, an engagement trial was defined as a trial in which the negative face was presented in the opposite location of the preceding cue. This is because these trials measure the likelihood that participants will shift their attention toward the negative face. By contrast, for disengagement trials, the negative face was presented in the same location as the preceding cue. Therefore, participants were required to disengage their attention from the negative face to respond to a subsequent probe in the opposite location. Higher scores for the attentional engagement bias index reflected facilitated attentional orienting toward the angry expression. More specifically, scores above zero represented faster responding on trials where participants had to shift their attention from the location of the neutral face to the location of the angry face than trials in which they were required to maintain their attention at the location of the neutral face. Furthermore, as reported previously, for the engagement conditions, the probe appeared behind the angry face on 50% of the trials and behind the neutral face on 50% of the trials. The equation is as follows:

Attentional Engagement Bias Index =

$$\left(\begin{array}{l} \text{Cue in locus of neutral facial image:} \\ \text{RT for probe in locus of neutral facial image} \end{array} \right) \textit{minus} \left(\begin{array}{l} \text{Cue in locus of neutral facial image:} \\ \text{RT for probe in locus of negative facial image.} \end{array} \right)$$

Similarly, higher scores for the attentional disengagement bias index reflected greater difficulty disengaging from the angry expression. More specifically, scores above zero represented faster responding on trials where participants maintained their attention to the location of the angry face compared with trials when they were required to shift their attention to the opposite location. In addition, the probe appeared behind the angry face on 50% of the trials and behind the neutral face on 50% of the trials. The equation is as follows:

Attentional Disengagement Bias Index =

$$\left(\begin{array}{l} \text{Cue in locus of negative facial image:} \\ \text{RT for probe in locus of neutral facial image} \end{array} \right) \textit{minus} \left(\begin{array}{l} \text{Cue in locus of negative facial image:} \\ \text{RT for probe in locus of negative facial image.} \end{array} \right)$$

Results

One participant's data were excluded as they did not meet the criteria for being Caucasian, eight participants' data were excluded due to close to chance-level (<60%) accuracy on the arithmetic task, and a further three participants' data were excluded as their RTs were slower than 3.29 SDs from average. Therefore, 91 participants' data were included in further statistical analyses. Raw data are available here: https://osf.io/bex6q/

Mean accuracy on the probe task was 95.7% (*SD* = 4.0%) in the no-load condition, 97.1% (*SD* = 3.7%) in the low-load condition, and 94.1% (*SD* = 5.0%) in the high-load condition[5]. Mean accuracy on the arithmetic task was 88.6% (*SD* = 10.4%) in the low-load condition and 85.6% (*SD* = 8.8%) on the high-load condition. While correct RT was the primary measure of interest in this study, to ensure that there were no speed-accuracy trade-offs, accuracy data were also analysed. To this end, a 2 (trial type: engagement or disengagement) x 3 (load: no, low, or high) or 2 (probe: locus of negative face or locus of

[5] Note that the means reported here are derived from taking the average accuracy for the angry and neutral probe trials. These differ slightly from the aggregate mean scores provided in the raw data file, as those were computed prior to trial assignment (i.e., mean across all trials of this type, rather than mean of angry and neutral condition trials of this type). The means reported in text can be verified from the available raw data, by taking the average accuracy for the angry and neutral trials at each load.

neutral face) ANCOVA on probe identification accuracy with the continuous predictor variable of social anxiety was conducted. Social anxiety scores were centred on the grand mean to reduce multicollinearity and improve interpretability (see Tabachnick & Fidell, 2013). Violations in sphericity were corrected with the Greenhouse-Geisser estimate. A significant effect was found for load, $F(1.72, 153.43) = 15.91$, $p < .001$, $\eta_p^2 = .152$. No other significant main or interaction effects were found ($p \geq .093$), indicating that accuracy did not differ based on participants' or the probe location. Follow-up analyses consisted of ANCOVAs concurrently comparing two load conditions (averaged across the other factors) with social anxiety as a covariate. These revealed that accuracy for the probe was significantly higher in the low-load condition compared with both the no-load condition, $F(1, 89) = 10.96$, $p = .001$, $\eta_p^2 = .110$, and the high-load condition, $F(1, 89) = 27.00$, $p < .001$, $\eta_p^2 = .233$. In addition, accuracy was significantly higher in the no-load condition compared with the high-load condition, $F(1, 89) = 7.70$, $p = .007$, $\eta_p^2 = .080$. Therefore, participants had the highest accuracy on the low-load condition, followed by the no-load condition, and then the high-load condition.

Exclusions were made for trials in which RTs were less than 100ms or greater than 2.5 standard deviations above the individual participant's mean RT for each load condition separately. The percentage of excluded trials based on RT outliers were 2.7%, 3.1%, and 3.1% for the no-load, low-load, and high-load load conditions, respectively. Data from trials in which participants performed incorrectly on the probe task were also excluded from further analyses as, on these trials, participants may not have been attending in the correct location at the beginning of the trial. In addition, in the low-load and high-load conditions, trials in which participants responded incorrectly on the arithmetic task were excluded as the load manipulation may not have been successful. Each participant's mean performance was then calculated for each condition. The percentage of total excluded trials (i.e., combined RT and

WM task accuracy exclusions) were 2.7%, 16.5%, and 21.6% for the no-load, low-load, and high-load conditions, respectively.

Next, the two bias indices were calculated to establish an attentional engagement bias index and an attentional disengagement bias index for each participant in the no-load, low-load, and high-load conditions. These bias scores were subjected to a 2 (trial type: engagement or disengagement bias) x 3 (load: no, low, and high) ANCOVA with the continuous predictor variable of social anxiety. Any violations in sphericity were corrected with the Greenhouse-Geisser estimate. This analysis revealed a significant effect for trial type ($F(1, 89) = 14.58$, $p < .001$, $\eta_p^2 = .141$) as the mean engagement bias index was lower (M = -23.9ms) than the disengagement bias index (M = 19.1ms). In addition, a significant effect was found for load, $F(1.77, 157.60) = 5.54$, $p = .007$, $\eta_p^2 = .059$. The mean bias scores in the no-load, low-load, and high-load conditions were 3.4, 8.5, and -19.2, respectively. Follow-up analyses, ANCOVAs that compared the mean bias score (averaged over engagement and disengagement) in two levels of load at a time with social anxiety as a covariate, revealed that the bias scores in no-load and low-load conditions did not significantly differ from one another (F<1). However, the no-load bias ($F(1, 89) = 5.56$, $p = .021$, $\eta_p^2 = .059$) and low-load bias ($F(1, 89) = 8.22$, $p = .005$, $\eta_p^2 = .085$) were significantly higher than the high-load bias scores.

Finally, and most importantly, a significant interaction between type of trial, load condition, and social anxiety was revealed, $F(1.70, 151.64) = 5.18$, $p = .010$, $\eta_p^2 = .055$. To further explore this interaction, separate analyses were conducted for the engagement bias and disengagement bias results.

Engagement Bias

An ANCOVA with 3 levels of load (no-load, low-load, and high-load) and a continuous predictor variable of social anxiety was conducted on the engagement bias. This analysis revealed a main effect for load, $F(1.69, 150.49) = 3.94$, $p = .028$, $\eta_p^2 = .042$. The engagement biases in the no-load, low-load, and high-load conditions were -17.9, -9.0, and -44.8, respectively. Subsequent ANCOVAs comparing engagement biases and two load levels at a time with the social anxiety covariate included revealed that the engagement biases did not significantly differ in the no-load and low-load conditions ($F<1$). However, the difference between the engagement biases in the no-load and high-load conditions were trending toward significance ($F(1, 89) = 3.74$, $p = .056$, $\eta_p^2 = .040$), and the difference between the engagement biases in the low-load and high-load conditions was significant ($F(1, 89) = 5.53$, $p = .021$, $\eta_p^2 = .059$). This indicates that, under high-load, the engagement bias was reduced.

In addition, a significant interaction effect was found between load and social anxiety, $F(1.69, 150.49) = 4.46$, $p = .018$, $\eta_p^2 = .048$. The relationship between social anxiety and the engagement bias was then analysed separately for the three load conditions using Pearson correlational analyses. For the no-load condition, a significant positive correlation was found between the engagement bias and social anxiety, $r = .26$, $p = .012$. This relationship is illustrated in Figure 2.

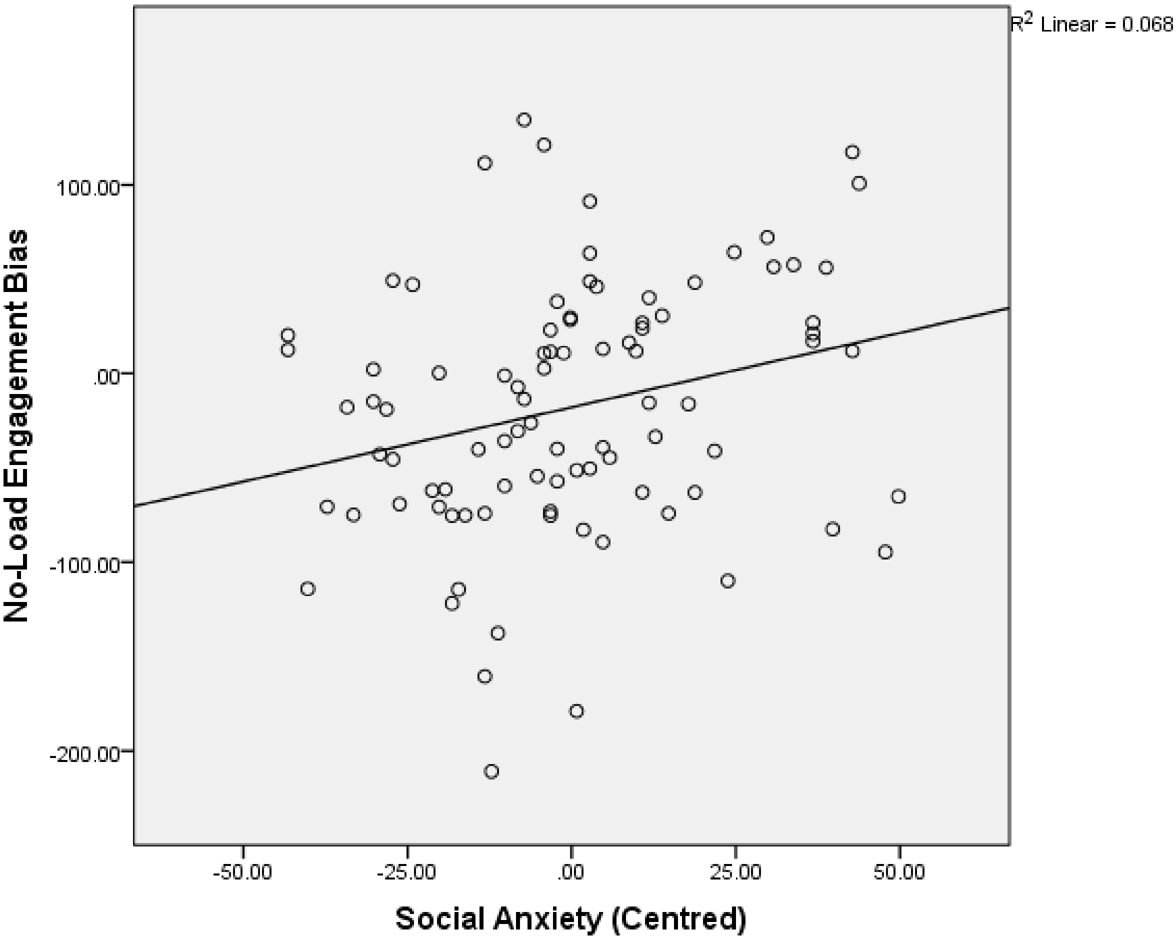

Figure 2. Graphical representation of the relationship between social anxiety (x-axis) and the engagement bias to threat (y-axis) under no additional working memory load.

For the low-load condition, the correlation between the engagement bias and social anxiety was not significant, $r = -.05$, $p = .651$. This relationship is demonstrated in Figure 3.

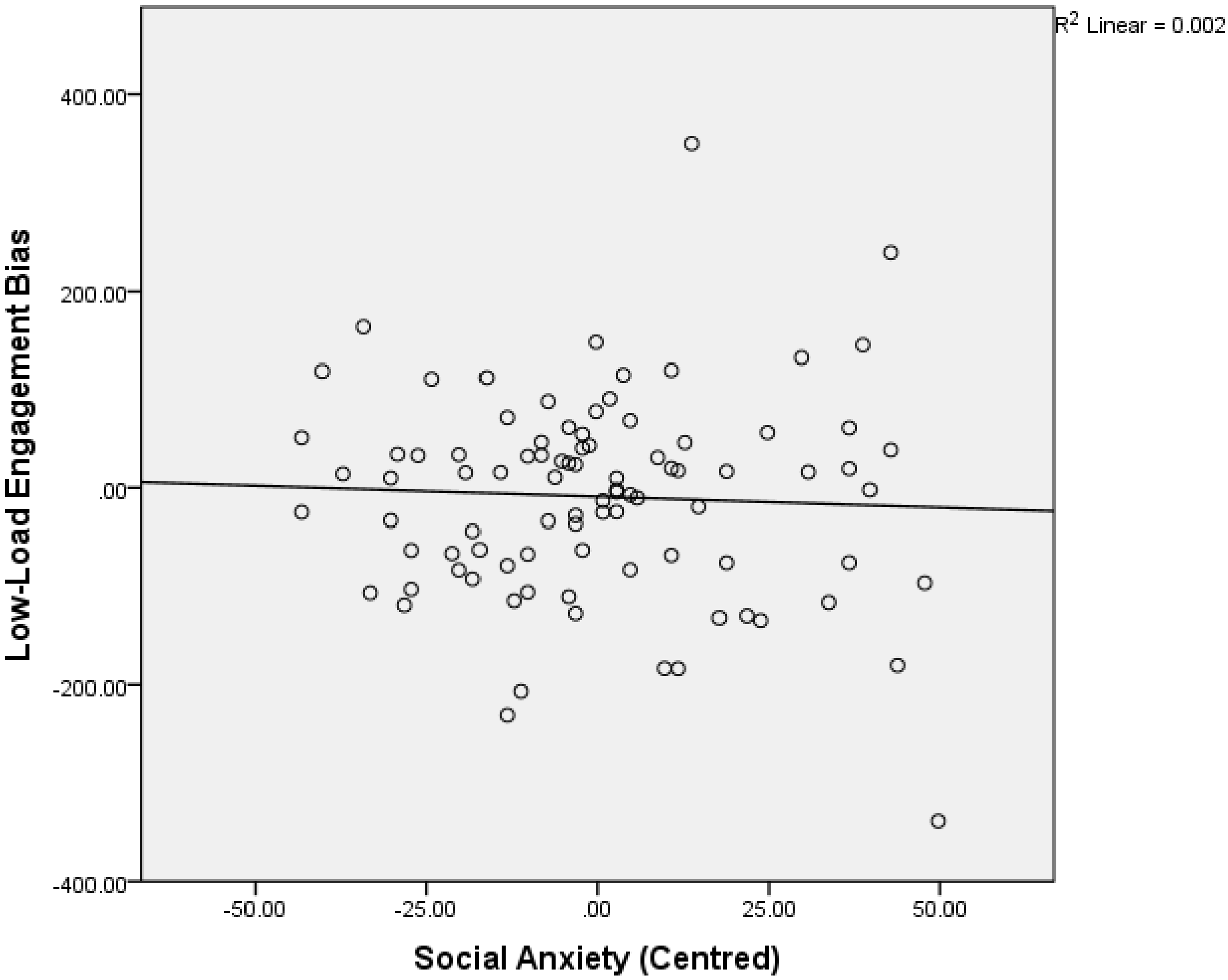

Figure 3. Graphical representation of the relationship between social anxiety (x-axis) and the engagement bias to threat (y-axis) under low working memory load.

For the high-load condition, the correlation between the engagement bias and social anxiety was not significant, $r = -.18$, $p = .090$. This relationship is demonstrated in Figure 4.

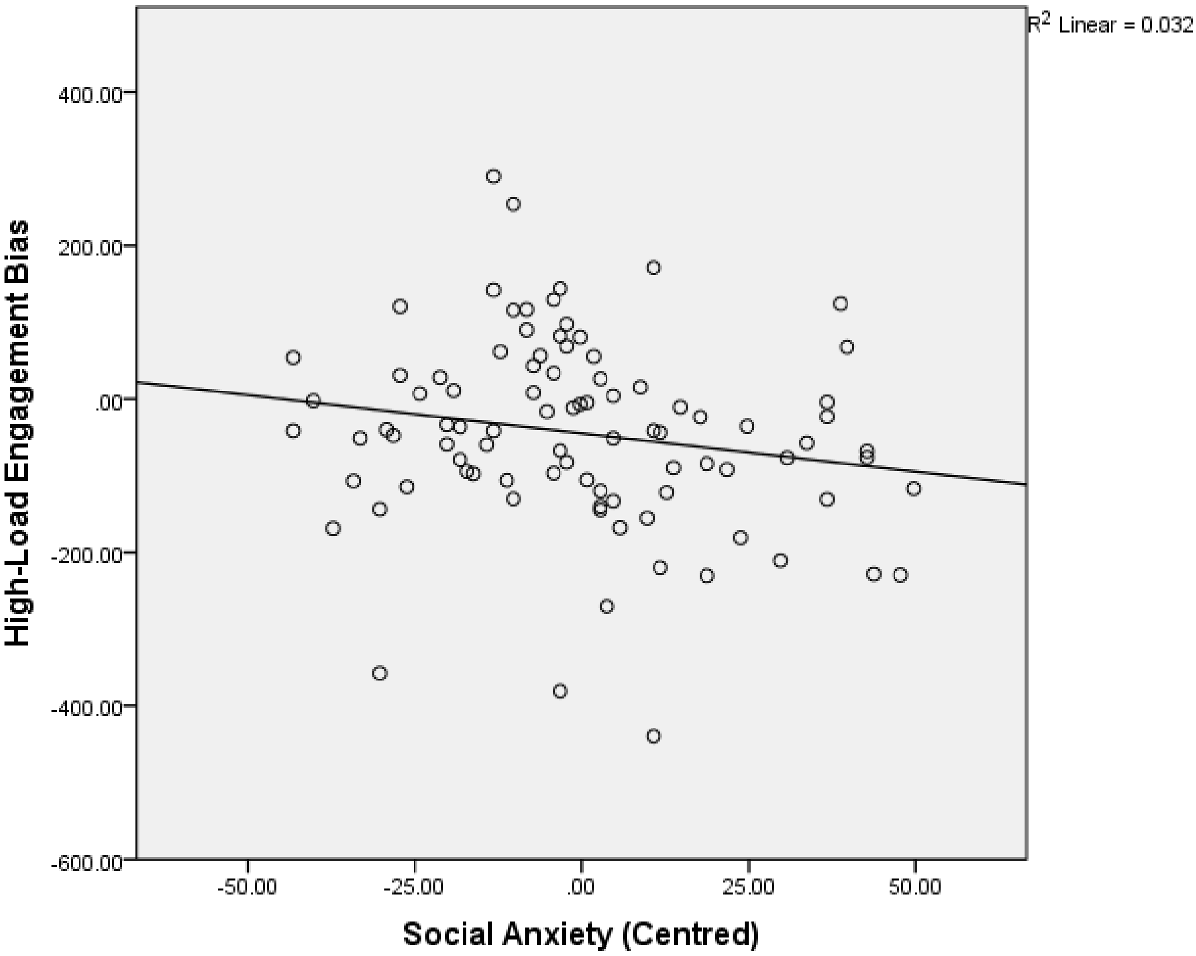

Figure 4. Graphical representation of the relationship between social anxiety (x-axis) and the engagement bias to threat (y-axis) under high working memory load.

Disengagement Bias

To assess the relationship between social anxiety and the attentional disengagement effect, a 3 (load: no-load, low-load, and high-load) ANCOVA with the continuous predictor variable of social anxiety was conducted on the disengagement bias. Neither the main effect of load ($F(1.74, 154.80) = 1.31$ $p = .270$, $\eta_p^2 = .015$) nor the interaction between load and social anxiety ($F(1.74, 154.80) = 1.74$, $p = .183$, $\eta_p^2 = .019$) were significant.

Gender Effect

Past research has found that face recognition may be impacted by the gender of the face and the gender of the observer (e.g., Wells, Gillespie, & Rotshtein, 2016). For instance, a happy face advantage has been found for female faces (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Hess, Blairy, & Kleck, 1997; Tucker & Riggio, 1988) whereas anger has been found to be more readily recognised for male faces (Becker et al., 2007). Therefore, to test the effect of face and participant gender on bias scores, the bias scores were subjected to a 2 (face gender: male or female) x 2 (participant gender: male or female) x 2 (trial type: engagement or disengagement bias) x 3 (load: no, low, and high) ANCOVA with the continuous predictor variable of social anxiety. No significant main or interactive effects were observed for face gender ($ps \geq .318$) or participant gender ($ps \geq .164$).

Discussion

The present study sought to further understand the attentional mechanisms underlying social anxiety by testing the role of top-down attention in engaging and disengaging attention from threatening facial expressions. This was achieved by testing engagement and disengagement effects under three WM load conditions: no-load, low-load (simple arithmetic question), and high-load (difficult arithmetic question). Social anxiety was not associated with delayed disengagement from threat. However, higher levels of social anxiety were associated with enhanced engagement with threat. In addition, load moderated the engagement bias, thus implicating the role of top-down attention in this bias.

Social Anxiety and an Engagement Bias toward Threat

In the current study, the results of the no-load condition were a partial replication of Grafton and Macleod's (2016) findings. Grafton and Macleod found that high social anxiety was associated with an engagement bias toward negative facial expressions. The current study found a similar effect, with higher levels of social anxiety associated with an increased engagement bias. A slight difference between the two studies though was that the overall means in the current study were negative not positive. That is, Grafton and Macleod reported a mean engagement bias of 46.67ms for participants with high social anxiety and 12.66ms for participants with low social anxiety. When a median split is applied to the current data (see Appendix A), participants with high social anxiety have a mean engagement bias of -2.31 and participants with low social anxiety have a mean engagement bias of -33.12ms. On initial consideration, it does not appear that we observed an engagement bias toward threat as on average participants did not respond faster to the probe following the threatening face compared with the neutral face. However, we contend that the current findings reflect the early stages of shifting attention toward the threatening face. That is, participants were generally faster following the neutral face because their attention had been secured by the previously presented cue in that location. Then, as seen from Figure 2, there is a linear relationship between increased engagement bias scores and social anxiety. In fact, the participants (n = 30) scoring above the cut-off for "probable" social anxiety on the LSAS-SR (score of 60) had a mean engagement bias of 3.20. In addition, participants (n = 10) scoring above the cut-off for "highly probable" social anxiety (score of 90) had a mean engagement bias of 10.89. This indicates that participants with high social anxiety were shifting their attention away from the cued location *toward* the threatening expression.

Furthermore, although the engagement biases in the current study differ from Grafton and MacLeod's (2016) study, the *difference* in engagement bias between the low and high social anxiety groups were almost identical. Grafton and Macleod reported engagement bias means of 46.67ms for participants with high social anxiety and 12.66ms for participants with low social anxiety, which corresponds to a mean difference between groups of 34.01ms. The mean difference between participants with low and high social anxiety in the current study was 30.81ms. This indicates that the same pattern of results between participants with low and high social anxiety were found.

The major difference in methodology between the current study and Grafton and MacLeod's study is the presentation times of the faces. Grafton and Macleod (2016) presented the faces for 500ms and 1000ms durations, and found that social anxiety was associated with an engagement bias for the 500ms but not the 1000ms duration. The current study utilised a 200ms duration. It is, therefore, likely that at this duration participants had only just started to shift their attention from the cued neutral face to the threatening face. That is, the bias likely falls within a temporal window; at 200ms duration, participants with high social anxiety may start shifting their attention away from the neutral face toward the threatening face, then at 500m duration, they may have fully engaged attention at the threatening face, and then this bias may no longer be present after 1000ms of duration.

The current study also extended on Grafton and Macleod's study by testing whether the engagement bias is driven by top-down or bottom-up attention. This was achieved with the addition of a WM load. This had previously been tested by Boal et al. (2018) who did not replicate Grafton and MacLeod's (2016) finding of enhanced engagement under no-load. Boal et al. also found no effect of additional WM load on engagement biases. However, there were several limitations undermining Boal and colleagues' (2018) design, which have been improved in the current study (as discussed in the introduction). Both the current study and Grafton and MacLeod's (2016) study found evidence that social anxiety is associated with an engagement bias to threat. One possibility, therefore, is that Boal and colleagues' finding that social anxiety was associated with a *reduced* bias to threat may be because participants with higher levels of social anxiety had greater attention to the inverted threatening faces. Furthermore, contrary to Boal and colleagues' study, the current study found that the engagement bias to threat for socially anxious participants was eliminated by load. We posit that this discrepancy in results may be because the load task in Boal et al.'s study (digit-span) may not have been sufficiently complex to exhaust the participants' WM resources, unlike the arithmetic task in the current study.

Since enhanced attention to threat was eliminated with the addition of load, the results indicate that shifting attention to an angry face for socially anxious individuals is dependent on the availability of WM resources. Thus, the engagement bias toward threat is not automatic but is instead reliant on top-down attention. Indeed, this bias was eliminated even under low-load. This indicates that the threat bias is only found when individuals have few requirements on WM and they can, thus, allocate those spare resources to attending to threat. This finding challenges the evolutionary perspective that anxiety results in enhanced bottom-up threat detection. LoBue (2014) found that individuals have a bias toward curvilinear lines (representative of snakes) and that anxiety increases this bias. However, LoBue did not employ an additional WM load to test if this bias is bottom-up or if it requires WM resources. This raises the possibility that either all engagement threat biases are driven by top-down attention or, although bottom-up detection occurs with curvilinear lines, it does not occur with more complex categories such as faces. Further research is needed to test these possibilities.

Social Anxiety and a Disengagement Bias from Threat

The disengagement results were consistent with Grafton and MacLeod's (2016) findings, whereby social anxiety was not associated with delayed disengagement effects under no-load. Furthermore, the disengagement bias was not significantly affected by the addition of load. These findings help elucidate the discrepancy found in the attentional literature. That is, past research has found that social anxiety is associated with preferential attention to threat (Mogg & Bradley, 2002; Mogg, et al., 2004; Pishyar, Harris, & Menzies, 2004), avoidance of threat (Chen, Ehlers, Clark, & Mansell, 2002; Mansell, Clark, Ehlers, &

Chen, 1999), or no biases at all (Gotlib et al., 2004; Ononaiye, Turpin, & Reidy, 2007; Pineles & Mineka, 2005). As seen from the findings of the current study, this discrepancy in the literature may be better understood if further research separately measures engagement and disengagement biases and considers the impact of WM task demands on attentional biases.

Limitations and Further Directions

One potential limitation of this study is that, due to separating the trials into distinct blocks, the load tasks could have induced differences in mood. For example, participants may have felt more anxious in the high-load block than the no- and low-load blocks. In order to test this explicitly, future research could consider intermixing the trials within the same block. Secondly, the study only included angry-neutral face trials. To ensure that these results specifically reflect a threat bias, it would be necessary to test that the bias is not found for other expressions, such as happy and sad faces.

Thirdly, the present design did not measure the potential effect of inhibition of return from the cued location. It is possible that the engagement bias may be influenced both by participants shifting attention toward the threatening face, as well as inhibition of return to the initially cued location. One method of testing this would be to include neutral-neutral trials. If similar engagement bias scores are found for neutral-neutral trials as for angry-neutral trials, this would indicate that inhibition of return is driving the effect. However, if socially anxious participants have a bias to threatening faces only, this would support the conclusion that social anxiety is associated with an engagement bias to threat.

Note that here we have interpreted the bias scores as reflecting an attentional bias associated with (i.e., enhanced engagement with and delayed disengagement from) the angry faces, with the neutral faces simply serving as the control comparison stimulus. There are very strong theoretical reasons to favour this interpretation, since bias toward threat is at the heart of key models of social anxiety (Rapee & Heimberg, 1997, Wong & Rapee, 2016) and there is also empirical support for this notion (Grafton & MacLeod, 2016, Mogg et al., 2004, Pishyar et al., 2004). It is therefore legitimate to interpret the biases in the way that we have. However, from an alternative perspective, the pattern of results observed could instead reflect attentional processes driven by the neutral face that was paired with the angry face. Again, there are clear reasons not to favour such an interpretation. However, even if one were to run with this interpretation, our overall conclusion – that the observed bias is modulated by working-memory load – still stands. Since automatic processes are thought to be impervious to concurrent cognitive load, this has clear, novel, and important theoretical implications about the nature of the bias.

In summary, the current study suggests that attentional engagement with threat for individuals with social anxiety is driven by top-down attentional mechanisms. These findings can now be used to inform interventions targeted at reducing social anxiety. Attentional training has been used to attempt to alter cognitive biases to threat. Typically, a dot-probe paradigm is employed with the probe almost always replacing the neutral stimuli, thus training the individual to attend to neutral stimuli rather than threatening stimuli. A recent meta-analysis (Liu et al., 2017), found that attentional training for individuals with social anxiety is associated with a small to medium reduction in the threat bias and a small reduction in symptoms of social anxiety. Based on the results of the current study, it is likely that these changes in attentional biases and symptoms rely on changes in top-down attention, such as cognitive control. Further research could measure if cognitive control moderates the benefits received from attentional training. In addition, individuals with poorer cognitive control could receive training to improve their top-down attention to help them reduce their engagement bias with threat. The results of the current study indicate that further research should focus on targeting the engagement bias toward threat and not the disengagement bias, which does not appear to play a large role for individuals with higher levels of social anxiety.

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Open Practices Statement

None of the experiments was preregistered. Raw data are publicly available, see https://osf.io/4yks8/.

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Chapter Nine. Summary and Further Directions

Chapter Overview

This chapter summarises the main findings of this thesis, focusing on theoretical implications and further directions for research. The main topics of discussion are engagement and disengagement attentional biases, the role of attentional control when orienting to emotional faces, and top-down attentional contributions to the threat bias associated with social anxiety. This chapter also considers the interactions between the race of participants and the photographic face stimuli employed, as well as the role of top-down attention toward temporal threat biases.

The current thesis has made several major findings. Specifically, this research employed a modified dot-probe design with emotional faces to determine the underlying mechanisms driving attention to faces, the limits to attentional control for socially anxious individuals, and the role of top-down attention in biases to threat. Chapter Five reported our discovery that participants from an unselected sample were able to use top-down attention to orient rapidly to cued facial expressions. However, attentional orienting toward the cued faces was disrupted when the faces were inverted, likely indicating that subjects required holistic processing of the face to rapidly orient toward it rather than relying on piecemeal processing (e.g., focusing only on the eyes or mouth). In addition, attention to faces was not significantly affected by selection history, either across repeating trials or block of trials. Chapter Six extended the findings of Chapter Five and found that social anxiety was not associated with a general deficit in attentional control. Instead, deficits only emerged for participants with high social anxiety when orienting to a happy face in the presence of a threatening distractor face. It was discovered that the threat bias for socially anxious individuals was characterised by differences in engagement with threat and not disengagement from threat (Chapters Seven and Eight). Finally, Chapter Eight revealed that enhanced engagement with threat for individuals with high social anxiety was driven by top-down, and not bottom-up, attentional guidance.

Social Anxiety and Engagement With and Disengagement From Threat

Summary of Findings and Implications

There are three components of attention to threatening stimuli; facilitated engagement, delayed disengagement, and avoidance (Cisler & Koster, 2010). Past attempts to measure later attentional processes, such as delayed disengagement and avoidance of threat have often confounded these processes with engagement with threat (Judah, Grant, Lechner, & Mills, 2013; Koster, Crombez, Verschuere, & De Houwer, 2004). Chapters Seven and Eight of the present research used a recently developed paradigm, which allows these processes to be separately assessed (Grafton & MacLeod, 2014, 2016; Rudaizky, Basanovic, & MacLeod, 2014). In this paradigm, participants' attention is initially secured either towards the location of a threatening face or in the opposite location in order to provide separate measures of engagement and disengagement biases. Modifications of this design were utilised in Chapters Seven and Eight of this thesis. Specifically, in Chapter Seven, an upright threatening or neutral face was paired with its inverted counterpart on each trial, and in Chapter Eight, a threatening and a neutral face were paired together on each trial, rather than employing inverted faces. Findings from the two studies concurred with respect to the effects of social anxiety on disengagement but differed with respect to the observed effects on engagement with threat. That is, both Chapter Seven and Chapter Eight found that social anxiety was not associated with differences in disengaging attention from threatening faces relative to neutral faces but showed differences with regard to engagement. This indicates that when the processes of engagement and disengagement are de-confounded, it is the processes of engagement, not disengagement, that differentiate socially anxious individuals.

Surprisingly, as reported in Chapter Seven, higher levels of social anxiety were associated with a *reduced* engagement bias to threat. This contrasts with the theoretical models of Rapee and Heimberg (1997) and Wong and Rapee (2016), which posit a bias toward threat in social anxiety. One possibility is that the presentation time (500ms) was too long and, so, participants may have initially engaged with threat but then rapidly avoided it, which meant that the dot-probe task only measured this second attentional process of avoidance. However, this possibility is questionable given that Grafton and MacLeod (2016) utilised a 500ms presentation time and found an engagement bias with threat for socially anxious individuals. Another possibility is that this unexpected finding stems from the nature of the paired image (intended to be non-threatening) presented at the same time as the threatening image. The choice of paired image on the dot-probe task has previously been found to impact the measurement of attentional bias. For example, Chen, Ehlers, Clark, and Mansell (2002) found that socially anxious participants had a bias away from faces, regardless of the emotion, when faces were paired with household objects. Therefore, in Chapter Seven, socially anxious individuals may have had a reduced engagement bias because, rather than focusing attention on the upright disgust faces, they were instead orienting to the paired inverted disgust faces. Indeed, participants could have initially oriented to the upright face and then had time in the 500ms presentation to orient to the inverted disgust face. Since social anxiety is characterised by hypervigilance to threat, socially anxious individuals may be more likely to monitor both obvious signs of threat (upright disgust faces) and ambiguous signs of threat (inverted disgust faces), compared with participants with lower levels of social anxiety.

The study reported in Chapter Eight was conducted to address this issue. In this study, threatening and neutral faces were paired together on each trial and a briefer presentation time (200ms) was used. This time it was found that higher levels of social anxiety, relative to lower levels of social anxiety, were associated with *enhanced* engagement with threat. This is consistent with Rapee and Heimberg's (1997) model of social anxiety, as described below. Moreover, since the study in Chapter Eight also corrected for the ambiguity in the threat value of the paired image in Chapter Seven, there is good reason to believe that these results best characterise the nature of the threat bias in social anxiety. That is, Chapter Eight more accurately reveals the attentional processes associated with social anxiety when individuals are faced with unambiguous threat in competition with a neutral stimulus. That said, it would be interesting in future research to further examine the nature of this potential bias toward *ambiguous* threat as, for example, a study could compare attention to inverted and rotated disgust expressions paired with neutral faces to test if socially anxious individuals have a bias toward threat, even when it is inverted or rotated (and, therefore, the identity of the expression is ambiguous). This will reveal whether socially anxious individuals have hypervigilance to ambiguous signs of threat. Such a study should also include images of happy faces to determine whether socially anxious individuals are hypervigilant to ambiguous threat specifically, or any ambiguous signs of social evaluation. It may also be worthwhile to assess the presentation times of the faces, as this bias may only occur at longer presentation times (e.g., 500ms), to allow individuals enough time to process the inverted face.

Finally, a digit-span memory task, which only requires information maintenance in memory, was used in Chapter Seven whereas an arithmetic task requiring information to be maintained and manipulated in memory was used in Chapter Eight. We postulate that an arithmetic task may be more effective at exhausting WM resources, though further research may be needed to confirm this interpretation. Additional research is also needed to further understand the impact of WM load on executive and visuospatial stages of attention. That is, in line with past research, the current study conceptualised WM load as affecting top-down attention. However, another possibility is that WM load may also impact the visuospatial stage of information processing. We do not believe that this is a likely explanation of the current findings as past research has found that WM load reduces perceptual processing for inattentional blindness tasks, in which the distractor is presented unexpectedly (Fougnie & Marois, 2007; Todd, Fougnie, & Marois, 2005). However, the distractors in the dot-probe task were expected and other research using expected distractors have found the opposite pattern of results – increased visual distraction occurs under high WM load (see Lavie, 2005). Nevertheless, these conflicting findings highlight the importance of further research testing the role of WM load on both executive and visuospatial stages of visual attention.

The results of Chapter Eight results are consistent with the results of Grafton and MacLeod (2016) who found engagement biases but not disengagement biases toward threat for individuals with social anxiety. These findings emphasise the importance of separately measuring engagement and disengagement biases so as not to confound the two effects with one another, as they are separate attentional processes. According to Rapee and Heimberg's (1997) cognitive-behavioral model, social anxiety is associated with both enhanced engagement and delayed disengagement from threat. Biased attention to signs of disapproval from others confirms the individual's prediction that he or she is being negatively evaluated, which further increases his or her levels of anxiety. The results of Chapter Eight only partially support Rapee and Heimberg's predictions, finding evidence for enhanced engagement but not delayed disengagement from threat. This indicates that Rapee and Heimberg's model requires updating to emphasise engagement biases with threat rather than disengagement biases. In addition, due to the differing results between Chapters Seven and Eight, in which a bias away from threat was found in one study and a bias toward threat was found in the other study, it is recommended that future models predict the situations under which biases toward and away from threat may be found.

Further Directions

The current research has furthered our understanding of the threat bias indicating that, for rapidly presented images, socially anxious individuals experience enhanced engagement but not delayed disengagement from threat. However, open questions remain regarding attentional processes at later stages of attention (e.g., avoidance of threat), the processes of covert and overt attention, and variability in attention to threat. Past attempts to measure attentional avoidance of threat (e.g., Judah et al., 2013) have used long presentation times for images, arguing that this provides a measure of later stages of attention. However, this approach confounds components of attention such as enhanced attention, delayed disengagement and avoidance and does not allow for the measurement of variability in attention across time (e.g., shifts in engagement with threat, avoidance, and re-engagement with threat over time).

An emerging area of research is the use of eye-tracking technology to measure attentional biases across time. Some studies have measured eye-movements to emotional faces for individuals with social anxiety. However, as with RT data, there have been inconsistent results. Several studies have found that social anxiety is associated with increased dwell time on threatening stimuli (Gamble & Rapee, 2010; Lazarov, Abend, & Bar-Haim, 2016; Schofield, Johnson, Inhoff, & Coles, 2012). By contrast, other research has found evidence for rapid attentional orienting to emotional stimuli (though not threat-specific stimuli) for individuals with social anxiety with concurrent high state anxiety (Garner, Mogg, & Bradley, 2006). Several studies have also found that social anxiety is linked with differential responding to positive stimuli. For example, Schofield, Inhoff, and Coles (2013) found that, across 1500ms of image presentation on a dot-probe task, socially anxious individuals attended less to emotional expressions compared to control participants, whereas control participants preferentially attended to positive expressions. In addition, further research found that socially anxious individuals disengaged attention from positive stimuli more readily than negative stimuli (Chen, Clarke, MacLeod, & Guastella, 2012) and, during a public speaking task, socially anxious individuals had an overall avoidance of emotional stimuli and reduced engagement of attention with positive stimuli (Chen, Clarke, MacLeod, Hickie, & Guastella, 2016). Finally, Singh, Capozzoli, Dodd, and Hope (2015) found that socially anxious participants, relative to low trait anxious participants, more rapidly engaged attention to neutral faces but had no differences in attention to angry faces. This body of research indicates that socially anxious participants may have biased overt attentional orienting both toward threatening stimuli and away from positive stimuli.

These results should be interpreted with caution due to inconsistent findings. Some of this inconsistency may be because eye-movement research assesses overt attentional shifts but not covert attention. Saccadic eye movements are essential to develop a detailed and accurate mental representation of our visual field. Specifically, eye movements allow the foveal, which has high acuity, to process important parts of the visual field. Attentional shifts can also occur, though, without accompanying eye-movements, as covert attentional shifts result in enhanced processing at attended locations (Mangun et al., 2001; Posner, 1980). Indeed, research indicates that attention can guide eye-movements, either facilitating or suppressing a saccade to an attended location (Belopolsky & Theeuwes, 2009). As suggested by Singh et al. (2015), one possible explanation for the lack of threat bias found in their eye-tracking study was that, on neutral-angry face pair trials, socially anxious participants may have covertly attended to the angry face and then avoided orienting toward it (thus overtly orienting to the neutral face more rapidly instead of the angry face). The measurement of overt attention alone (through the use of eye-movement data) cannot provide information on the possibility of covert attentional shifts that result in suppressed saccades to the location of threat. To more thoroughly understand the interplay between overt and covert attention, it is recommended that eye-movement technology should not replace visual tasks using RT and accuracy data (e.g., dot-probe, visual search, and spatial cueing tasks). Instead, eye-movements can be measured in conjunction with accuracy and RT data in visual experiments to provide a more thorough assessment of attentional biases.

Another reason to be hesitant about relying on eye-movement data alone is that there have been limited research on the reliability of eye-tracking technology. For example, Waechter, Nelson, Wright, Hyatt, and Oakman (2014) recently reported that eye-tracking technology has low reliability for first fixations and the proportion of viewing time in the first 1,500ms. However, eye movements indices (the proportion of fixation frequencies and proportion of viewing time) were found to have good reliability across the total 5,000ms image presentation. It is, therefore, recommended that further research computes and reports the reliability of eye-tracking to refine the use of this technology.

The dot-probe task has also been associated with low reliability. With an unselected university sample, Schmukle (2005) and Staugaard (2009) assessed split-half and test-retest reliabilities of the dot-probe task. Schmukle (2005) employed words and pictures and measured each participant's split-half reliabilities on bias scores, finding low reliability estimates (all below r = 0.20). In addition, test-retest reliability estimates, comparing bias scores measured with a one-week interval, were also low, ranging between -.22 and +.32. Similarly, using photographic faces, Staugaard (2009) reported split-half estimates ranging between -.29 and +.37, and test-retest reliability estimates ranging between -.24 and +.26. Using a sample of high and low socially anxious participants, these findings have been replicated by Waechter et al. (2014), revealing that bias scores (i.e., difference scores calculated from invalid and valid trials) had low reliability. However, raw RT scores had good reliability (estimates = +.85-.96). These researchers argued that the low reliabilities for bias scores were likely because of high correlations between conditions.

Interesting, Bar-Haim et al. (2010) reported higher reliability estimates on bias scores using a dot-probe tasks with a civilian population living near the Gaza Strip, reporting a split-half reliability of $r = +.45$, $p < 0.0001$. It is possible that this result may reflect sampling error. However, another possibility is that the sample or design characteristics of this study resulted in higher reliability rates. As with eye-tracking data, it is recommended that further research compute and report reliability estimates. This will guide our understanding of the conditions under which the dot-probe task may have higher reliability.

However, rather than necessarily reflecting an issue with the dot-probe task or eye-tracking technology, it is possible that the low reliability estimates indicate that attention to threat is characterised by high variability. It is, therefore, critical to assess trial-by-trial variability in attending to threat when considering the temporal dynamics of the threat bias. To illustrate, consider this possibility: in an experiment, an individual displays strong enhanced engagement with threat on half of the trials and strong avoidance of threat on the other half of trials. By contrast, another individual consistently displays no biases toward or away from threat throughout an experiment. When their overall mean RTs are measured, both appear to have no biased attention to threat even though their patterns of responding over the experiment were markedly different. It is crucial that variability in attentional patterns is assessed fully to properly understand the threat bias processes.

Using a dot-probe task, Zvielli, Vrijsen, Koster, and Bernstein (2016) have developed an elegant approach to measure variability in attending to threat. Specifically, results from temporally contiguous pairs of congruent trails (in which the probe followed a threatening image) were subtracted from results from incongruous trials (in which the probe followed a neutral image) to calculate a trial-level bias score. This study found that, compared with healthy control participants, spider phobic participants displayed enhanced variability in attending to spider-related material throughout the experiment. This indicates that biased attention to threat fluctuates across time. The importance of measuring variability in attention is further supported by a growing body of literature (Bardeen, Daniel, Hinnant, & Orcutt, 2017; Cox, Christensen, & Goodhew, 2018; Gladwin, 2017; Iacoviello et al., 2014; Naim et al., 2015; Schäfer et al., 2016; Swick & Ashley, 2017; Zvielli, Bernstein, & Koster, 2015). For example, Cox et al. (2018) found that trait anxious participants displayed greater fluctuations in attentional bias to negative stimuli compared with neutral stimuli. It is, therefore, recommended that, in addition to mean levels of performance, further research should measure and assess individual variability in performance.

The Role of Attentional Control When Orienting to Emotional Faces

Summary of Findings and Implications

Chapter Five investigated the general attentional principles underlying attention to emotional faces, finding that participants could use top-down attention to rapidly attend to emotional faces. Furthermore, no cueing effects were found when the faces were inverted, likely suggesting that top-down attentional processes require holistic face processing. Note that there has been debate regarding holistic processing of inverted faces, with some researchers proposing that inversion leads to quantitative not qualitative changes in face processing (e.g., Richler, Mack, Palmeri, & Gauthier, 2011; Sekuler Gaspar, Gold, & Bennett, 2004; though see Rossion, 2008 for a response). One alternative explanation is that inversion disrupts the meaningfulness and recognisability of the individual face parts (e.g., it may be difficult to perceive a mouth as smiling when it is inverted). To test this, further research can use faces in which the individual face parts are intact and presented upright but are scrambled. If cueing is not found for scrambled faces, this would offer further support to the conclusion that holistic face processing is required for rapid top-down attentional orienting to emotional faces.

Finally, no evidence of selection history was found. Chapter Six extended on this research, finding that high social anxiety was associated with selective deficits in orienting to happy faces when paired with a threatening distractor face, but not in the other conditions. This indicates that social anxiety is not associated with a generic deficit in top-down control but, instead one that is selectively activated in the presence of distracting (non-task relevant) threat. In addition, it was found that social anxiety was not associated with differences in selection history to emotional faces. That said, however, no selection history effects were found for any of the participants, which may have limited our ability to observe anxiety-specific effects.

According to Peschard and Philippot's (2016) model, working memory (WM) serves as an interface, resolving information from external and internal sources. Attentional focus is influenced by several factors, including task goals, attentional control, emotional or motivational value, long-term memory, stimulus salience, and selection history. These researchers proposed that social anxiety may be associated with differences in selection history effects, which may be associated with increased rumination following exposure to a social situation. However, the current study found that, with an unselected sample, selection history appeared to play no role in attentional orienting to emotional faces. This was supported by both trial-by-trial analyses and keeping the same expression constant across a block of trials (Chapter Five). In addition, no relationship was found between social anxiety and selection history effects (Chapter Six), indicating that, even for participants with high social anxiety, selection history did not significantly contribute to attentional orienting to emotional faces.

The observed lack of selection history effects was surprising given that selection history effects have been well-documented using basic visual stimuli, such as shapes and colours (Belopolsky & Awh, 2016; Theeuwes, Reimann, & Mortier, 2006; Theeuwes & Van der Burg, 2011). Indeed, Theeuwes (2013) argued that feature-based attentional orienting is the result of selection history (referred to as bottom-up priming) but not top-down attentional control. However, although top-down attention may play a minimal role in the presence of pop-out visual arrays, Belopolsky and Awh (2016) confirmed that top-down attention guides orienting for visually complex arrays. In their task, participants were presented with a verbal colour cue and viewed a six-circle array and then asked to identify the target and report the orientation of a line presented within it. When the target was a different colour to the distractors (pop-out design), selection history effects were observed but top-down knowledge of the target did not reliably improve performance. By contrast, when pop-out effects were eliminated as the target and distractors were all presented in unique colours, both selection history and top-down attention had separate contributions to target detection. Thus, the findings of the current research offer confirmatory evidence for the role of top-down attentional control for attentional orienting to complex scenes (i.e., faces). However, it also raises the question: why was selection history effects not found in the current study?

As discussed in Chapter Five, there are several possibilities for why selection history effects may not have been found in the current research. Firstly, selection history effects may only emerge for basic visual stimuli but not for complex stimuli, such as photographic faces. Secondly, in the current research, selection history effects were measured by repeating the same facial expression across trials, but the actual photograph could change (i.e., a photograph of a happy face from one individal could change to a happy face of a different individual). Thus, selection history effects may be limited to repetition of identical exemplars, and not generalise to category-level effects. Thirdly, selection history effects may only emerge for particular tasks. In standard selection history paradigms, participants make a response about the stimulus that is repeated. However, in the dot-probe task in the present research, participants respond to a separate stimulus (the probe) from the stimuli that they had used to guide their attention (i.e., the face). It is possible that selection history effects may have emerged if participants were required to respond to the identity of the face itself (e.g., its gender). The fact that there were no selection history effects for low or high anxious participants indicates that we have discovered important boundary conditions for selection history effects, but it also possibly constrained our ability to observe differences between individuals with respect to selection history. Therefore, further research is needed to disentangle these possibilities for why a selection history effect was not found. Then further research can be conducted confirming the role of selection history in the guidance of attention to threat for individuals with high social anxiety.

Peschard and Philippot's (2016) also proposed that socially anxious individuals have a general deficit in attentional control, and that this may be moderated by the social threat value of the visual stimuli. Similarly, Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007) proposed that anxiety impairs the functioning of goal-directed, top-down attention and increases the influences of bottom-up attention. Therefore, anxious individuals may have particular difficulty inhibiting attention to threat. Furthermore, similar to Peschard and Philippot's model, Attentional Control Theory proposed that anxious individuals also have general deficits in the ability to inhibit attention to distracting stimuli. However, these deficits will not always be observable as anxious individuals may engage in compensatory strategies, such as increased effort on the task. Nevertheless, deficits will be observable under particular situations, such as when multiple attentionally demanding tasks are performed at once.

The current study found that socially anxious participants had deficits in top-down control in the presence of a threatening distractor when orienting attention to happy faces. However, a general deficit in attentional control was not found, as the socially anxious participants were able to successfully orient to the cued faces in all other conditions. One possible inference, therefore, is that deficits in attentional control are more likely to be revealed in the presence of social threat, but general deficits may only occur under particular conditions. Previous research exploring attentional control has found that social anxiety is associated with lower self-reported attentional control (Moriya & Tanno, 2008). In addition, Wieser, Pauli, and Muhlberger (2009) found that, on an antisaccade task with faces, individuals with high social anxiety had a higher antisaccade error rate regardless of emotional expression, indicating that they had difficulty inhibiting reflexive orienting to facial expressions. Liang (2018) investigated the issue further employing a non-emotional mixed antisaccade task, testing socially anxious and non-anxious control participants in both blocked conditions (in which they only either performed pro- or antisaccades) or a mixed condition (in which the performance of pro- and antisaccades could vary on a trial-by-trial basis). These researchers found that that, in blocked conditions, socially anxious participants had longer antisaccade latencies compared with non-anxious control participants but had no differences in prosaccades or error rates. By contrast, in the mixed condition, the socially anxious participants had longer latencies for both pro- and antisaccades. This indicates that socially anxious participants consistently demonstrated difficulties with inhibition to distracting stimuli and, also, demonstrated greater difficulties on the mixed task, either due to difficulties shifting between two tasks or because of the impact of higher cognitive load. Deficits in attentional control to non-emotional stimuli for socially anxious individuals, therefore, may be particularly evident on more demanding tasks. In sum, Wieser et al. (2009) found that socially anxious participants had a general deficit in attentional control in response to all faces, rather than a specific deficit when threatening faces were employed, and Liang (2018) found general attentional control deficits in the absence of emotional stimuli.

This raises the question: why was a general deficit in attentional control found on the antisaccade task for socially anxious participants but the present research found a specific deficit in attentional control in the presence of distracting threat? One possibility is that the antisaccade task may be more attentionally demanding than the dot-probe task. Therefore, deficits in attentional control may be more likely to be revealed in the presence of threatening distractor stimuli but general deficits may emerge on difficult tasks. Further research is needed to systematically test the conditions under which these deficits in attentional control emerge for socially anxious individuals.

Further Directions

Due to our important finding that poor attentional control may underlie attentional capture by threatening distractors, the next avenue for follow-up research aimed at developing therapeutic strategies for people with Social Anxiety Disorder is the use of effective training techniques to improve attentional control. As discussed in the introduction of this thesis, Attention Bias Modification (ABM) has emerged as a potential treatment of social anxiety in which participants are trained either to attend to positive or neutral stimuli and ignore threatening stimuli. However, the results have been inconsistent, with some studies finding that ABM has resulted in reduced social anxiety (Amir et al., 2009; Amir, Weber, Beard, Bomyea, & Taylor, 2008; Heeren, Reese, McNally, & Philippot, 2012; Li, Tan, Qian, & Liu, 2008; Schmidt, Richey, Buckner, & Timpano, 2009), but other studies failing to replicate that finding (Boettcher, Berger, & Renneberg, 2012; Carlbring et al., 2012; Heeren, Lievens, & Philippot, 2011; Julian, Beard, Schmidt, Powers, & Smits, 2012; McNally, Enock, Tsai, & Tousian, 2013). In addition, some studies have even found that training to attend to threat resulted in reduced anxiety (Boettcher et al., 2013; Klumpp & Amir, 2010).

One possibility is that attentional control moderates these improvements in anxiety. This possibility was tested by Basanovic, Notebaert, Grafton, Hirsch, and Clarke (2017). To assess attentional control, individual differences in the ability in inhibit attention to goal-irrelevant stimuli and the ability to selectively attend to goal-relevant stimuli were measured. Participants also completed a single-session ABM task, in which they were trained to encourage an attention bias either toward threat or away from threat. This study found that increased attentional control was associated with changes in attentional bias in the direction encouraged by the ABM procedure, with both inhibition and selection independently contributing to change in bias. In addition, these differences did not differ depending on whether participants were trained to attend or avoid negative stimuli. Note that this study did not assess changes in emotional state or anxiety after attentional training and so it is not known whether differences in attentional control also moderated improvements in anxiety after training. However, given the change in bias scores – which are typically associated with anxiety – it is promising from a therapeutic perspective that attentional control is an important moderating variable in clinical outcomes for ABM.

Consistent with this notion, Cohen et al. (2016) experimentally investigated the effects of trained attentional control and found that this led to neurobiological changes that would be consistent with reduced psychological anxiety, although unfortunately this was not specifically measured. In this experiment, participants completed training with an arrow flanker task with either 80% incongruent trials or 20% incongruent trials. Training with a higher proportion of incongruent trials necessitates the engagement of attentional control in subjects. The amygdala, which is a key brain area responsible for processing emotional stimuli, was then measured with functional magnetic resonance imaging (fMRI). It was found that participants who received the training with the 80% incongruent trials had lower amygdala activation to emotional stimuli relative to the participants who received training with the 20% incongruent trials. This is a very interesting result as it demonstrates that training with non-emotional stimuli to improve attentional control results in a reduced impact of emotional content in the brain.

Further evidence for the effect of attentional training on clinical outcomes comes from Sari, Koster, Pourtois, and Derakshan (2016), who conducted WM training with high trait anxious participants. Over a three-week period, participants engaged in daily attentional training with an adaptive dual n-back task, in which participants were required to remember the association between a letter and its location on a screen and respond to matches with previous trials. It was found that attentional training resulted in improvements in attentional control, as assessed by both performance on a flanker task and resting state electroencephalography (EEG). Overall anxiety symptoms did not significantly improve in the training group or control group. Instead, improvements in anxiety only occurred for participants with high engagement in the training task. This research indicates that attentional control training is a promising new avenue of research and that further research should consider the moderating variable of engagement in training.

The current study found that deficits in attentional control are particularly apparent for individuals with social anxiety in the presence of distracting threat. One possibility, therefore, is that attentional training to teach individuals to ignore threat could result in greater gains than attentional training with neutral stimuli. It is recommended that these two training programs be compared, by assessing which program leads to the greatest gains in attentional control, reduced attentional biases to threat, and reduced levels of social anxiety. This line of research will help optimise attentional training programs to target symptoms of social anxiety.

Social Anxiety and Top-Down Contributions for the Threat Bias

Summary of Findings and Implications

Bottom-up attention to threat facilitates survival, allowing individuals to rapidly orient to and respond to potential survival risks (e.g., snakes and spiders) (Kenrick, Neuberg, Griskevicius, Becker, & Schaller, 2010; Lang, Bradley, & Cuthbert, 1997; LeDoux, 1996;

LoBue, Rakison, & DeLoache, 2010; Mogg & Bradley, 1998; Öhman, 2007). The assumption of most threat-detection models has been that the threat bias in anxiety is driven by an overactive bottom-up attentional system (e.g., Eysenck et al., 2007; Öhman, 1996, 2005; Öhman & Wiens, 2004). In a review by Cisler and Koster (2010), the eight most influential models of attentional bias in anxiety were identified: Beck and Clark's (1997) cognitive model, Williams, Watts, MacLeod, and Mathews' (1988) model, Öhman's (1996) feature detection model, Wells and Matthews' (1994) model, Mogg and Bradley's (1998) cognitive-motivational model, Mathews and Mackintosh's (1998) model, Eysenck et al.'s (2007) attentional control theory, and Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and van IJzendoorn's (2007) model. Of those models, only Wells and Matthews' (1994) does not include a bottom-up, automatic threat-detection system. Their model, instead, proposes that anxious individuals hold a belief that it is important to monitor threat, thus resulting in a threat bias.

In Chapters Seven and Eight, two possibilities were tested: (1) individuals with higher levels of social anxiety may have deficits in top-down control, leading to difficulties inhibiting attention to the bottom-up capture of attention to threatening stimuli; or (2) individuals with higher levels of social anxiety may have a chronic top-down attentional set for threat. That is, even when given a competing goal (e.g., attend to happy faces), they maintain an attentional set regarding threat detection that is difficult to overcome. This is consistent with previous research, which has found that participants can hold multiple attentional control sets concurrently (Adamo, Pun, Pratt, & Ferber, 2008). Therefore, when instructed to attend to positive stimuli, individuals with higher levels of social anxiety may simultaneously maintain an attentional set for threat, leading to difficulties shifting attention to positive stimuli. These two possibilities result in different predictions about how the attentional bias toward threat in social anxiety will fare under conditions of WM load which tax shared top-down resources**.** Specifically, possibility one predicts that biased attention to threat associated with high social anxiety would be unaffected by the load manipulation. However, possibility two predicts that, if top-down attentional resources are required for participants to shift toward the threatening faces, the engagement bias will reduce in the high-load condition. The current thesis (Chapter Eight) found evidence for the second hypothesis indicating a chronic top-down set for threat. This is because the engagement bias toward threat was eliminated under WM load which taxed shared top-down resources. The current research contradicts the dominant view that the threat bias in socially anxiety is bottom-up, finding instead that it requires top-down resources. This finding indicates that top-down goals and beliefs are integral to the conceptualisation of threat detection for socially anxious individuals.

The current study did not assess the specific top-down beliefs that could drive biased attention to threat. However, Clark and Wells (1995) and Rapee and Heimberg (1997) predicted that maladaptive beliefs underly biased attention to threat. Clark and Wells (1995) identified three categories of maladaptive beliefs for socially anxious individuals; (1) excessively high standards for social performance (e.g., “I must always be witty and intelligent”), (2) conditional beliefs concerning social evaluation (e.g., “if I show my feelings, others will reject me”), and (3) unconditional beliefs about the self (e.g., “I’m stupid”, “I’m different”, “I’m unattractive”). These self-beliefs may lead individuals to interpret social situations (e.g., going to a party) as dangerous, motivating them to monitor their environment for signs of threat. These two cognitive models diverge with respect to their predictions about biased attention to threat, as Clark and Wells predicted that socially anxious individuals engage in self-focussed attention at the expense of attention to external signs of threat, whereas Rapee and Heimberg predicted that socially anxious individuals engage in biased attention to both internal and external signs of threat. The current findings are consistent with

Rapee and Heimberg's (1997) prediction that, in socially-evaluative situations, socially anxious individuals preferentially allocate attention to critical facial expressions. Rapee and Heimberg also predicted that this biased attention to threat can be extremely unhelpful as it reinforces negative self-beliefs and beliefs that others are judgemental and rejecting, resulting in increased social anxiety.

The current study found that top-down orienting to emotional faces was present for upright faces but eliminated for inverted faces. Inversion disrupts the ability to process a face holistically, as instead individuals rely on piecemeal processing of individual face parts (Mondloch & Maurer, 2008; Searcy & Bartlett, 1996; Yin, 1969). Attentional orienting can be associated with space-, feature-, or object-based attention. The results of the current study likely indicate that participants were not simply orienting to individual facial features (e.g., the mouth or eyes). Instead, the top-down set for the cued face relied on object-based attention. This is consistent with other research that has assessed object-based attention to faces. For example, O'Craven, Downing, and Kanwisher (1999) presented participants with images of a house and face transparently superimposed on one another, with one moving whilst the other remained stationary on each trial. Participants were instructed to either attend to the face, house, or motion of one of the objects. Attention to different attributes of the attended and unattended objects was assessed with fMRI. This study found that, although the three attributes shared the one location, attending to one attribute of an object resulted in enhanced neutral processing of both the cued attribute as well as the task-irrelevant attribute of that object. For example, attending to the motion of a face resulted in changes in the blood oxygen level dependent (BOLD) signal to the middle temporal/medial superior temporal area responsible for motion, as well as the fusiform face area responsible for processing faces. Therefore, attention to a face resulted in enhanced neural representation of all attributes of the face, rather than attending only to task-relevant features. In addition, these results could not be explained by a space-based model of attention as participants displayed an enhanced neural response to the attended object compared with the unattended object, even though they occupied the same position in space. The results of the current study further add to this research, suggesting that object-based attention can be used to orient to specific emotional expressions, such as anger and happiness.

Further Directions

Further important avenues of research are to develop a more thorough understanding of the relationship between top-down beliefs and the threat bias and investigate how interventions aimed at changing these beliefs may reduce the threat bias. Firstly, to develop a thorough predictive model of the threat bias, further research should investigate whether the degree to which an individual endorses particular socially-relevant beliefs is associated with the threat bias. For example, individual differences in each of the three types of beliefs formulated by Clark and Wells (1995; high standards for performance, social-evaluative beliefs, and negative self-beliefs) could differentially predict the threat bias. In addition, Rapee and Heimberg (1997) proposed that increased threat detection is not stable as the process is activated in social situations in which there is a perceived audience. The relationship between the type of social-evaluative situation (e.g., speech task, small-group task etc), the type of beliefs that are activated, and the degree of bias toward and/or away from threatening facial expressions could be investigated.

An additional avenue of research is to investigate whether altering particular social-evaluative beliefs results in similar reductions in biased attention to threat. The purpose of cognitive therapy is to identify and challenge unhelpful cognitive beliefs. One avenue for further research, therefore, is to measure the threat bias before participants receive cognitive therapy aimed at altering social beliefs. Following therapy, further research can assess whether the degree of change in those beliefs predict changes in the threat bias.

Impact of Race on Face Processing

Although it was beyond the scope of this thesis, it is recommended that further research explores the relationship between the race of participants, the race of the faces employed, and biased attention to threat in social anxiety. Previous research has found that people tend to have better recognition for the identity and emotional expressions of own-race faces compared with cross-race faces (for a review, see Young, Hugenberg, Bernstein, & Sacco, 2012). This difference appears to be associated with different processing styles for faces. For example, Goldinger, He, and Papesh (2009) conducted an experiment in which they measured Caucasian and Asian participants' eye-movements and pupil diameters when viewing faces in preparation for a recognition memory test. These researchers found that, compared with cross-race trials, on own-race trials participants displayed more fixations to facial features, briefer gaze times per fixation, more fixations to unique features, and fewer regressions. Blais, Jack, Scheepers, Fiset, and Caldara (2008) also found race-based face processing effects, as individuals from different cultures demonstrated different processing patterns for examining faces, with Caucasian participants focusing more on the eyes and East Asian participants focusing more on the nose and mouth. Furthermore, initial evidence indicates that patterns of vigilance and/or avoidance of attention to other-race faces is influenced by threat-value (Trawalter, Todd, Baird, & Richeson, 2008), visual novelty (Al-Janabi, MacLeod, & Rhodes, 2012), and external motivation to appear non-prejudiced (Bean et al., 2012).

The experiments of Chapters Five, Six, and Eight employed Caucasian faces and only tested Caucasian participants; participant restrictions were chosen to minimise variability in the data due to cross-race effects. However, unfortunately, this also meant that the results were not necessarily representative of the general population. In Chapter Seven, which was conducted prior to the other studies, the images selected were Caucasian, but no race-based restrictions were placed on participants. Since this study was largely conducted over the summer holidays at the Australian National University and offered paid participation, a large number of international students who stayed in Australia over the university break participated in this study. That is, 33% of participants identified as Caucasian/White, 62% as Asian, 1% as Black and 4% as Hispanic. Although not reported in Chapter Seven, due to length restrictions on the published manuscript, post-hoc analyses were performed to assess the relationships between participants' race and engagement and disengagement biases to threat. To analyse the engagement bias, a repeated-measures ANCOVA was performed with the within-subject factor of load (no, low, and high), between-subjects factor of race (Caucasian and non-Caucasian), and the continuous variable of social anxiety. No significant main or interactive effects of race were found (ps $\geq .278$). Similarly, an ANCOVA was conducted assessing the disengagement bias scores, which revealed non-significant main and interactive effects of race (ps $\geq .164$). These analyses indicate that race did not have a large impact on attention to neutral and disgust faces on a dot-probe task. However, this study did not measure important race-related factors such as country of birth, childhood exposure to other-race faces, and time spent in Australia. Further research is needed to test the relationship between social anxiety and attention to same-race and cross-race faces for individuals of differing racial backgrounds.

Further Directions for Temporal Attentional Biases to Threat

The current thesis focussed on attentional orienting to threat across *space*. However, an additional avenue for research is understanding attentional biases across *time*. In everyday social interactions, facial expressions can change rapidly, such as from approving to disapproving (Goffman, 1967). Two paradigms that assess temporal biases to threat are emotion induced blindness (EIB) and the attentional blink (AB). In EIB, participants search for a target (e.g., a rotated landscape/architectural image) embedded in a stream of rapidly (e.g., 100ms/item) presented upright distractors (e.g., usually of landscape/architectural images). Research has found that participants are worse at detecting the target when it is preceded closely in time by an emotionally negative image compared with a neutral image (Most, Chun, Widders, & Zald, 2005; Most & Jungé, 2008). In addition, further research has found that participants who score higher on measures of harm avoidance (which is related to trait anxiety), have differential temporal threat detection. Specifically, in a study by Most et al. (2005), participants were either given a specific search strategy, in which they searched for a rotated image of a building, or a less specific search strategy, in which they searched for a rotated image that could either be a building or landscape. Harm avoidance did not predict differences in emotion-induced blindness for the non-specific attentional set condition. However, in the specific attentional set condition, lower levels of harm avoidance were associated with improved target detection. One likely interpretation of these findings is that participants with higher harm avoidance had reduced attentional control and so they were unable to overcome their threat bias even when given a specific search goal. That is, Most et al. suggested that attentional control could mediate the effects, as attentional control may have been used to filter out the irrelevant stimuli more efficiently, reducing the initial engagement with the threat and/or attentional control may have facilitated rapid disengagement of attention from the threatening images.

A second paradigm for measuring temporal attention biases is the AB task. In this task, participants view a stream of rapidly presented visual stimuli (e.g., letters and numbers) and try to identify two targets. An AB reflects the finding that the second target (T2) cannot be identified if it appears in close proximity (e.g., 200-300ms) to the first target (T1) (Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992). This design has been used with face stimuli to measure a threat-related AB associated with social anxiety. For example, de Jong and Martens (2007) presented participants with a stream of faces; the distractors were neutral faces that were rotated 180° and the T1 and T2 could either be of upright happy or angry faces, and participants were instructed to report how many faces in the stream were upright. Results were that participants displayed a reduced AB when T2 was an angry face. In addition, an angry T2 face resulted in greater difficulty identifying a happy T1 face. Neither of these effects were associated with high or low levels of social anxiety. This research, therefore, revealed an anger superiority effect but, surprisingly, this was not enhanced for participants with high levels of social anxiety. Subsequent research using letter stimuli as T1 and emotional faces as T2 found that emotional faces (happy and angry), resulted in an attenuated AB for the emotional faces relative to neutral faces, irrespective of social anxiety (de Jong, Koster, van Wees, & Martens, 2009). However, other research has found a differential AB associated with social anxiety, but only for participants with co-morbid depression; as these participants were less accurate at T2 identification if T1 consisted of a negative scene (Skinner & Ferguson, 2014). In addition, Morrison et al. (2016) found that participants with comorbid social anxiety and depression had reduced accuracy for T2 on a standard AB task (with letters and numbers). Morrison et al. (2016) posited that their results may be due to poor attentional control that is found for individuals with both high social anxiety and depression. However, since this is an emerging area of research, possible underlying mechanisms of a temporal bias to threat (or deficits in temporal attention to neutral stimuli) have not yet been tested.

In line with the findings of the current study, the body of literature on temporal attentional biases also indicates that attentional control may be a critical mediating factor linking social anxiety and biased attention to threat. Top-down attentional control may be critical to our ability to resist interference from threat detection both throughout our spatial environment, as well as from one moment to the next. It is recommended that further research measure the relationship between individual differences in attentional control and temporal attentional biases to threat, as well as the impact of attentional control training on these biases. However, the finding that temporal attentional biases to threat may only be found for participants with comorbid anxiety and depression is surprising. This points to the possibility that there may be some differences in the attentional mechanisms driving temporal and spatial biased attention. Further research is needed to understand the mechanisms driving temporal biases and to understand why they are present for individuals with comorbid social anxiety and depression but not for individuals with high social anxiety alone.

Conclusion

The evidence presented in this thesis challenges the dominant perspective that social anxiety is associated with an enhanced bottom-up bias to threat and, instead, indicates that the bias is driven by top-down attention. More specifically, the research comprising this thesis found that individuals with high social anxiety had enhanced engagement with threatening facial expressions, but this bias was eliminated when attentional top-down resources were depleted by a concurrent task. This is consistent with cognitive models of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997), which proposed that individuals with social anxiety believe that others have high expectations for their performance, that it is unlikely that they will meet up to these expectations, and failure to do so will be disastrous (e.g., lead to rejection). I predict that these beliefs result in top-down attention to sources of negative evaluation from others and this preferential attention likely confirms their socially-relevant beliefs, continuing to lead to biased attention to threat.

The research in this thesis also found that, when given a clear top-down set (e.g., attend to a happy expression), individuals with high levels of social anxiety had specific deficits in top-down control in the presence of distracting negative stimuli. It is, therefore, likely that the top-down goal of attending to threat is chronic with social anxiety and cannot easily be overcome by a competing goal. This research points to two particularly important predictions to be tested: firstly, it is predicted that modifying socially-relevant beliefs will lead to reductions in the threat bias, and secondly, training to enhance attentional control will enable individuals with high levels of social anxiety to orient to goal-driven stimuli rather than preferentially attending to threat. The findings of the current thesis provide critical information on the role of top-down attention to the threat bias associated with social anxiety. This marks a movement beyond simply measuring the threat bias to understanding the mechanisms maintaining it. As a deeper understanding of social anxiety is developed, we can move closer to breaking the reinforcing link between biased attention to threat and social anxiety. This will help individuals with high levels of social anxiety remove their “threat-coloured-glasses” and, rather than focusing on potential sources of judgment, attend to signs of acceptance and approval from others.

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