Developing Novel Approaches to Understanding Anxiety-Related Attentional Biases to Threat

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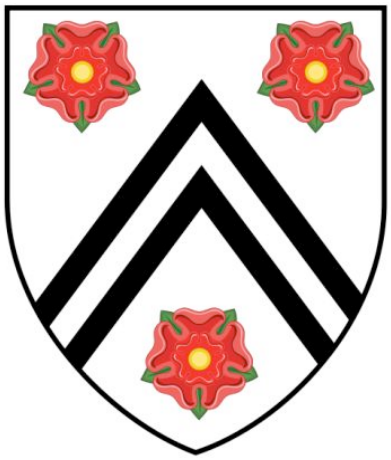
New College, Oxford

Trinity Term, 2018



A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy at the University of Oxford

Abstract

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Attention is guided by both endogenous cues, such as expectations stemming from memories, and by exogenous salience, such as stimuli conveying threat. The relative contribution of these cues in directing attention is in part determined by the dispositions of the observer. In particular, trait anxiety is proposed to be marked by excessive attention to, paired with subsequent difficulty in disengaging from, threatening material.

In this thesis, I explore the relationship between endogenous and exogenous sources of bias and how their relative weighting in guiding attention is modulated by trait anxiety. In particular, Chapter 2 and Chapter 3 present studies that assessed how contextual memories and long-term spatial memories, respectively, interact with threat salience to guide attention in trait anxious individuals. Results of the study in Chapter 2 showed an inability in extracting spatial regularities from contexts containing faces, independent of emotion. Instead, the first study presented in Chapter 3 revealed that anxiety interfered with the recruitment of long-term memories when specifically threatening distracting information was presented. A follow-up study suggested that this interference was contingent on the duration between memory cue and target, with an elimination of anxiety-related impairments at short durations. In Chapter 4, I present a study that explored how age affects the relative input of memory cues and biases to threat in guiding attention, with findings revealing impaired recruitment of long-term memories in anxious older adults when threatening distractors were presented during memory retrieval. However, results also showed a puzzling deficit in memory recruitment, across distractor emotion, for non-anxious older adults. Chapter 5 presents the final study, the aim of which was to develop an experimental task capable of measuring the temporal dynamics of orienting attention toward and away from relevant and irrelevant threatening stimuli. The N2pc electrophysiological marker was used in order to obtain a precise measure of attentional selection. While anxiety was not included, the study was intended as a basis for future research regarding the chronometry of threat biases in trait anxiety. Finally, Chapter 6 discusses the findings from the various studies so as to form a cohesive understanding of the contributions that this research has made toward explaining anxiety-related attentional biases to threat. The chapter also discusses limitations of the studies and interesting avenues for future research that builds on the body of research presented in this thesis.

Approximate Word Count: 45,000

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Table of Contents

1 General Introduction

1.1 Attentional Biases in Anxiety

The influx of sensory information in our environment places extreme demands on our perceptual systems. Our attentional system copes with these demands by prioritising stimuli for focal attentional processing. The biased competition view of attention proposes that this prioritisation is driven by both bottom-up (exogenous) and top-down (endogenous) inputs. Whilst the bottom-up pathway is governed by stimulus salience, the top-down pathway involves control processes that are observer-driven and that correspond to current task demands (Desimone & Duncan, 1995). The bottom-up pathway is particularly potent in biasing attention when stimuli are negatively charged. Our attentional system is highly proficient at detecting stimuli that signal potential peril. Selective attention to threatening information serves an evolutionarily adaptive purpose by facilitating the selection and execution of appropriate responding (i.e. fight or flight) (Öhman, Flykt, & Esteves, 2001). However, extreme vigilance to threat that consistently governs perception can play both a causal and reinforcing role in anxiety disorders (Mathews, 1990; Mathews & MacLeod, 1994). Thus, whereas adaptive detection to highly threatening information is common across all individuals, independent of vulnerability dispositions, anxiety is plagued by a heightened and prolonged attentional focus on threatening stimuli at the expense of processing task-relevant information. This attentional bias to threat consequently increases levels of anxiety, creating a vicious cycle. Studies in which threat biases are directly modified through training procedures have established the critical role played by preferential attention to threat in the cause and maintenance of anxiety disorders (MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). Such work has also been instrumental in identifying specific cognitive targets of

therapeutic interventions and in developing novel treatment approaches, such as attentional bias modification (Bar-Haim, 2010; Clarke, Notebaert, & MacLeod, 2014; Hakamata et al., 2010; MacLeod & Holmes, 2012; MacLeod & Mathews, 2012).

The impact of threat biases is exacerbated on account of the fluidity between attention and other cognitive systems, thereby enabling attentional threat biases to feed into other cognitive biases, such as those related to interpretation and memory that occur at later processing stages. For example, extended engagement with threat and a corresponding neglect of positive information (e.g. focusing on a single frowning face among smiling faces) can result in a negative interpretation of contexts (e.g. the group is negatively judging me), which may then create negative memory traces that influence upcoming decisions (e.g. I was rejected so I will avoid social situations). The cascading effects triggered by these early biases in attention therefore render them a key focus of clinical intervention.

Cognitive models of biases in anxiety uniformly posit heightened sensitivity to threatening stimuli, with appraisals of high threat causing a disproportionate amount of attention devoted to the threatening stimulus. Mogg and Bradley (1998) propose that the threat levels of incoming stimuli are assessed by a valence evaluation system and that anxiety is marked by a lower threshold for such evaluation, resulting in moderately threatening stimuli being deemed as highly threatening. Similarly, Williams, Watts, MacLeod, and Mathews (1988) posit an early mechanism of threat evaluation, the output of which is moderated by anxiety. The implication that attentional distortions occur at an early processing stage is further endorsed by the vigilance-avoidance hypothesis (Mogg, Bradley, Miles, & Dixon, 2004), which suggests that anxious individuals initially attend more readily to threatening information yet thereafter strategically avoid threat. However, the attention maintenance theory (also known as the delayed

disengagement theory) alternatively proposes that anxiety is characterised by prolonged engagement with a threatening stimulus, resulting from an impaired ability to disengage from the stimulus (Fox, Russo, Bowles, & Dutton, 2001; Weierich, Treat, & Hollingworth, 2008). The discrepancy between these models reflects the continued point of contention in the literature, regarding the precise chronometry of threat biases.

The exaggerated processing of threatening material is evident in clinical anxiety, trait anxiety, and transient state anxiety (Cisler & Koster, 2010; Mogg, Bradley, De Bono, & Painter, 1997). Biases are a feature of generalised anxiety disorder (Bradley, Mogg, White, Groom, & de Bono, 1999), social anxiety, panic disorder (Maidenberg, Chen, Craske, Bohn, & Bystritsky, 1996), and obsessive–compulsive disorder (Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996), with attentional biases specific to the relevant concerns of the particular anxiety disorder (Mathews & Macleod, 1985). For instance, Maidenberg et al. (1996) found that socially anxious patients took longer to respond to socially threatening words in the Stroop task but showed no differences in responding to more general threatening words. Although distortions in attention are more severe in clinical anxiety, they nonetheless mark both high trait and state anxiety. The relative effects of trait versus state anxiety on attention remain unclear, with the few studies directly comparing attentional biases in these two forms of anxiety yielding discrepant results (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007). Broadbent and Broadbent (1988) used the dot-probe task to demonstrate that attentional biases to threat were best predicted by individual differences in trait, rather than state, anxiety. As trait anxiety is a risk factor for clinical anxiety (Kotov, Gamez, Schmidt, & Watson, 2010), it is important to understand the underlying mechanisms of attentional biases in subclinical trait anxiety to develop preventative strategies. Thus, considering its role as a risk factor of clinical anxiety and the more

reliable evidence of attentional biases, trait anxiety was a major focus of this doctoral research. Nonetheless, state anxiety, as well as depression and neuroticism, which are often comorbid with trait anxiety, were collected and used in supplementary analyses.

1.2 Attentional Control and Sensory Gating in Anxiety

The attentional biases to threatening information that describe anxiety potentially stem from an overall impairment in sensory gating coupled with a corresponding deficit in attentional control. This phenomenon is posited to result from a broadening of the attentional field in anxious individuals in order to facilitate threat detection (Eysenck, Derakshan, Santos, & Calvo, 2007). Anxious individuals are plagued by persistent worry about the potential occurrence of threat that would interfere with current goals. Therefore, an adaptive preventative response is to cast attentional resources wide so as to ensure rapid detection of incoming threat (Eysenck et al., 2007).

Deficits in early sensory gating paired with resulting encumbered attentional processing of task-relevant information is described by the Attentional Control Theory (Eysenck et al., 2007). The theory is based on the presumption that there are two interactive attentional systems. The first is a stimulus-driven system that is governed by salient stimuli, while the second is goal-driven and relies on the utilisation of expectations and current goals to direct attention. The theory posits that anxious individuals exhibit a distorted weighting of these systems in favour of bottom-up stimulus salience, resulting in neglect of goal-driven behaviour.

Supporting evidence comes from a study employing pre-pulse inhibition of the startle reflex, which has been utilised as an index of sensorimotor gating. Here a stimulus eliciting a startle response (i.e. the pulse) is preceded by a weaker sensory stimulus (i.e. the pre-pulse) that

inhibits processing of the pulse so as to limit the intake of information. This adaptive mechanism to alleviate the burden on attention is impaired in anxious individuals, with studies showing reduced pre-pulse inhibition (Ludewig, Ludewig, Geyer, Hell, & Vollenweider, 2002). The implication that anxiety is marked by a more lenient threshold for filtering information is corroborated by evidence of an increased amplitude of the N1 event-related potential (ERP), a marker of early attentional allocation, in response to a neutral stimulus during a non-emotional visual discrimination task in participants with induced anxiety. The heightened N1 amplitude was paired with a reduced P3 potential, which indexes evaluation of task-relevant information[1] (Shackman, Maxwell, McMenamin, Greischar, & Davidson, 2011). Taken together, these findings show an anxiety-related disruption in task-directed performance.

While anxiety is marked by an overall relaxed gating for sensory information, the threshold is even lower for threatening information. The Attentional Control Theory explains that the distorted weighting of bottom-up over top-down processing is exacerbated if stimuli are threatening due to their greater salience (Eysenck et al., 2007). The greater access of threatening stimuli to early sensory processing results in facilitated access to memory, causing extended threat effects. Stout, Shackman, and Larson (2013) found that high trait anxious individuals allocated excessive working memory storage for threatening information, at the expense of task-relevant information. The privileged access of threat to working memory processing results in the intrusive and maladaptive thoughts that are characteristic of anxiety and enables the prolonged effect of threat, even in its absence. Long-term memories of threatening content obtain ready access to working memory, thereby becoming reactivated (Stout et al., 2013). Taken together,

[1] The precise nature of what the P3 potential indexes remains debated. Donchin & Coles (1988) first proposed that the P3 reflects 'context updating', suggesting that the P3 is elicited in response to deviations from expectancies, which in turn requires an updating of schemata of the environment. The term 'context', however, has been used interchangeably with 'working memory', with the conclusion that the P3 component reflects updating within working memory (Luck, & Kappenman, 2011).

findings suggest that impaired early sensory gating, allowing excessive input of bottom-up processing, contributes to the observed attentional biases to threat in anxious individuals.

1.3 Extant Paradigms for Measuring Anxiety-related Attentional Biases to Threat

Behavioural accounts of anxiety-related attentional biases to threat have shown decreased reaction times (RT) in detecting threatening target stimuli (Rinck, Becker, Kellermann, & Roth, 2003), impairments in inhibiting distracting threat (Fox, Russo, & Georgiou, 2005), and greater reliance on the gaze direction of fearful faces, compared to neutral faces (Mathews, Fox, Yiend, & Calder, 2003). These behavioural markers are corroborated by heightened neural responses to threat. Fearful faces have been shown to elicit heightened amplitudes of early ERPs related to emotional processing (e.g. frontocentral positivity), compared to neutral faces (Eimer & Holmes, 2002; Holmes, Vuilleumier, & Eimer, 2003), with more enhanced amplitudes evidenced in anxious individuals (Moser, Huppert, Duval, & Simons, 2008). Along the same lines, fMRI studies have revealed greater amygdala activation in response to fearful faces, compared to neutral and happy faces (Breiter et al., 1996; Vuilleumier, Armony, Driver, & Dolan, 2001). Similarly, an anxiety-related increase in amygdala activity in response to fearful faces has been found to be coupled with reduced activation in the dorsal anterior cingulate, a region implicated in top-down control mechanisms, suggesting exaggerated threat-related distraction and impaired ability in top-down reactive control processing (Bishop, Duncan, Brett, & Lawrence, 2004; Forster, Nunez-Elizalde, Castle, & Bishop, 2014).

The behavioural and neural evidence of threat biases derives from studies using various experimental paradigms (Bar-Haim et al., 2007). The dot-probe task (or attentional-probe task)

briefly presents a threatening stimulus paired with a neutral stimulus, most commonly words or pictures (MacLeod, Mathews, & Tata, 1986). The disappearance of the pair is followed by the appearance of a probe in the previous location of one of the stimuli. Participants are required to indicate the location of the probe (i.e. whether the probe replaced the left/right or top/bottom stimulus) or to identify the type of probe (e.g. a single dot or two dots). Both versions of the task have shown that probes supplanting the threatening stimuli are detected more quickly and probes replacing the neutral stimuli are detected more slowly. Although also evident in non-anxious participants, these effects are more robust in anxious participants (Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg & Bradley, 1998; Salemink, Hout, & Kindt, 2007).

The emotional adaptation of the Stroop task requires participants to name the colour of threatening and neutral words, thus requiring inhibition of the emotional semantic content. Studies that have administered this task to anxious participants have shown slowed colour naming to threatening, compared to neutral, words. Such enhanced semantic distraction is taken as a marker of an attentional bias to threatening stimuli (Williams, Mathews, & MacLeod, 1996), although there remains some debate regarding this interpretation.[2]

The emotional spatial cueing paradigm (Fox et al., 2001; Stormark, Nordby, & Hugdahl, 1995) uses threatening and neutral stimuli to cue the upcoming appearance of a target, with cues either validly or invalidly predicting the target location. Thus, contrary to valenced stimuli in the dot-probe task and the Stroop task, threatening stimuli in the spatial cueing paradigm require attentional processing for successful task performance. Larger validity effects, i.e. the difference in performance on trials with invalid cues and trials with valid cues, have been demonstrated for

[2] The slowed responding on the Stroop task has been postulated to instead reflect effortful avoidance of threat, rather than attentional engagement with threat (De Ruiter & Brosschot, 1994). Moreover, other accounts argue that the interference by threat results from a temporary response 'freezing' in the presence of threat (Algom, Chajut, & Lev, 2004).

threatening cues compared to neutral cues (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006). That is, reaction times were reduced on valid threat-cued trials and were increased on invalid threat-cued trials, compared to neutral-cued trials. Moreover, these effects are especially apparent in anxious individuals. That is, anxious participants show rapid orienting to the threatening cue, which facilitates performance on valid-cue trials. However, when the threatening cue is invalid, anxious participants experience difficulty in disengaging from the threat and thus show task disruption.

The visual search task has been used less frequently than the paradigms described above (Bar-Haim et al., 2007). The task requires participants to locate a single threatening stimulus within an array of neutral stimuli or to locate a neutral stimulus among threatening stimuli. Results stemming from this paradigm have demonstrated an anxiety-related decrease in reaction times to detecting threatening anomalies in neutral contexts and a reciprocal increase in reaction times to detecting neutral singletons within threatening matrices (Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Rinck et al., 2003).

While all these paradigms have greatly informed the current understanding of attentional biases to threat in anxiety, they are marked by limitations that leave room for alternative approaches to supplement extant findings. The extent to which existing paradigms tap into the same construct of attentional biases remains equivocal (Cisler & Koster, 2010; Mogg & Bradley, 2018). Correlations between results of the dot-probe task and those of the emotional Stroop task have been shown to be weak, signifying potential differences in the nature of the attentional biases being measured (Gotlib et al., 2004). Moreover, individual tasks have shown weak test-retest reliability and variations of a task also yield differing results, highlighting the sensitivity of task measures to changes in methodology. Kindt, Bierman, & Brosschot (1996) reported low test-

retest reliability of the emotional Stroop task and weak convergence between two versions of the task (card format and single-trial).[3] Strauss, Allen, Jorgensen, and Cramer (2005) likewise revealed poor reliability in the emotional Stroop paradigm, particularly demonstrating differential reliability coefficients when using response latencies versus difference scores. Similarly, Schmukle (2005) found weak test-retest reliability and weak internal consistency of verbal and pictorial versions of the dot-probe task. Chapman et al. (2017) attempted to explain the poor internal consistency of the dot-probe task by varying the stimulus-onset asynchrony (SOA). The authors reasoned that, as the typical 500 ms stimuli durations may be sufficient for initial orienting to be readily supplanted by disengagement, shortening the durations might reveal greater internal reliability. Results showed that while shorter durations did indeed exhibit increased reliability estimates, relative to longer durations, they nonetheless remained weak.

In addition to the variability within and between extant paradigms, they are also limited in ecological validity. In particular, they do not adequately reflect the complexities of our attentional system, which receives input from both endogenous and exogenous cues, and the complexities of our environment, within which stimuli occur.

1.4 Attention and Memory

Attention is guided by myriad internal and external influences (Theeuwes, 1994). Thus, attentional biases to threat do not operate independently but are instead accompanied by various other drivers of attention. One such key driver is endogenous long-term memory, in both explicit and implicit forms, which aids in the prioritisation of incoming information so as to guide

[3] The card format of the Stroop task presents words in sets of 20 and requires participants to read each out loud using a marked starting point. The single-trial format instead presents words individually and instructs participants to read each word out loud before they are shown the next word. The former format therefore includes distractor items, which may potentially exacerbate interference effects.

attention to pertinent stimuli. While attention and memory have largely been treated as independent cognitive systems, recent research has begun to explore their interaction (Patai, Doallo, & Nobre, 2012; Summerfield, Gitelman, Mesulam, & Nobre, 2006; Summerfield, Rao, Garside, & Nobre, 2011). Although the impact of attention on memory is well established (Cabeza, Ciaramelli, Olson, & Moscovitch, 2008; Ciaramelli, Grady, & Moscovitch, 2008), the relationship is bidirectional. Memories provide a cache of expectations about upcoming events, which facilitate perception and responding to upcoming relevant information (Nobre, 2018). The contextual cueing paradigm provides a clear demonstration of the influence that long-term memories exert on perception. The task presents arrays consisting of a single target among distractors. The key element is the repetition of some arrays that maintain a fixed spatial configuration between target and distractors over the course of the experiment. The learned regularities afforded by the repeated global spatial configurations facilitate target detection. Such facilitation leads to decreased response times when compared with response times to non-repeated arrays, a phenomenon known as the contextual cueing effect (Chun & Jiang, 1998). Studies that administered a recognition task, in which participants were asked to indicate whether arrays were repeated throughout the experiment, demonstrated a reliable lack of awareness of the repetitions (Chun & Jiang, 1998; Conci, Müller, & von Mühlenen, 2013). These findings have been taken to suggest that contextual learning operates on an implicit level, independently of conscious awareness (n.b. see Smyth and Shanks (2008) for counter argument),[4] driving predictions that facilitate search performance.

[4] Two experiments conducted by Smyth and Shanks (2008) suggest that participants showed conscious awareness of the repeated arrays underlying contextual learning. These findings emerged when the quantity of trials of a generation task, in which participants were asked to indicate the quadrant within which the target had been located, were increased fourfold from the 24 trials used in previous studies (Chun & Jiang, 2003). The authors similarly showed that contextual cueing was restricted to only those participants who showed explicit awareness of repeated arrays.

Further converging evidence of long-term memories effectively guiding attention is provided by the memory-guided orienting paradigm (Summerfield et al., 2006). In contrast to the implicit learning underpinning the contextual cueing paradigm, long-term memories in the memory-guided orienting task are formed via explicit learning. The task presents naturalistic scenes that contain embedded keys, which participants are asked to locate in an initial learning phase. Subsequent to forming these memories of unique target locations, participants perform a speeded detection task. Here each scene is presented briefly without the key in order to cue memories, after which the key appears in either the learned location (valid) or a novel location (invalid). Results of this task revealed quicker detection of targets in valid locations. These behavioural results were paralleled by heightened underlying engagement of the hippocampus (Summerfield et al., 2006), enhanced amplitudes of the visual P1 potential to valid target locations, and greater posterior alpha-band desynchronisation contralateral to remembered target locations (Summerfield et al., 2011). The results suggest changes in excitability within the visual cortex so as to aid anticipatory processing of attended stimuli. A variation of the memory-guided orienting task used a perceptual discrimination task, in which participants were instructed to determine whether target keys were present or absent in learned scenes, with present targets placed in either valid or invalid locations (Patai et al., 2012). This version of the task demonstrated increased perceptual sensitivity (d') for trials presenting valid target locations. The heightened sensitivity was accompanied by a reduction in the amplitude of the N2pc potential, which signifies target selection among distractors (Brignani, Lepsien, & Nobre, 2010; Luck & Hillyard, 1994). This reduction in amplitude may therefore be explained by the head start in processing provided by the cue scene, facilitating the selection processes occurring at target presentation (Patai et al., 2012).

Taken together, results underscore the ability of memories to direct attention effectively. The predictions about our environment provided by memories promote attention to information that is relevant to the observer, thereby supporting goal fulfilment. Thus, the exaggerated bottom-up salience that is a hallmark feature of anxiety operates in the context of top-down memory cues. When such memories are able to guide attention to task-relevant information, the ability of threat to command attention may diminish in potency.

The co-occurrence of exogenous threat and endogenous memories introduces interesting lines of inquiry. Does threat continue to receive prioritised access to sensory, and subsequent attentional, processing in the presence of endogenous memory cues that aid task performance? Specifically, how is attention guided when receiving input from both task-irrelevant threat and task-relevant memory cues? Can trait anxious individuals effectively employ endogenous cues to ensure task fulfilment and thereby overcome their inherent threat biases? Or is threat so potent in anxiety that it prevails over memories? These inquiries shift the exploration of anxiety-related attentional biases to a more ecologically valid context that considers memory cues, and therefore provide important contributions to the current understanding and conceptualisation of threat biases.

Throughout the studies in this thesis, fearful faces served as the threatening stimuli. These were used on account of their social and biological relevance (Fox, 2002; Rossignol, Philippot, Douilliez, Crommelinck, & Campanella, 2005). Since an expression of fear provides a signal of potential danger in one's environment, its quick detection and assessment is vital for appropriate responding. The rapid detection of threatening faces has been observed in studies using behavioural indices, neuroimaging, and eye tracking (Bradley, Mogg, & Millar, 2000; Eimer & Holmes, 2002; Eimer & Kiss, 2007; Holmes, Mogg, de Fockert, Nielsen, & Bradley, 2014). Trait

anxiety, rather than state anxiety, was selected as a focus for this thesis. As discussed above, trait anxiety is an indicator of a stable disposition and is an established risk factor of clinical anxiety (Kotov et al., 2010). Therefore, an understanding of attentional distortions in trait anxious individuals not only extends to clinical samples but also provides key insight into potential preventive strategies.

1.5 Aims

1.5.1 Primary Aim: Threat Biases in the Context of Memory Cues

The research presented in this doctoral thesis was motivated by (1) the compelling effect of memories on attention evidenced in non-anxious participants, and (2) the limited ecological validity of existing paradigms assessing attentional biases in anxiety. Taken together, these considerations underscore the necessity of novel approaches that investigate biases in anxiety in the context of memories. The overarching aim of the doctoral research was therefore to investigate how threatening information interacts with endogenous signals to dictate attention in trait anxious participants.

For this purpose, the contextual cueing paradigm and the memory-guided orienting paradigm were modified to incorporate threatening and neutral face distractors (Chapters 2 and 3, respectively). The emotional adaptation of these tasks enabled the assessment of how the recruitment of implicit and explicit memories, respectively, is affected by task-irrelevant threatening stimuli in trait anxious participants. In addition to this overarching aim, the memory-guided orienting paradigm was also used for two secondary aims, namely to explore: (1) the

chronometry of threat biases, and (2) potential age-related modulations of the recruitment of memories in the context of threatening distractors.

1.5.2 Secondary Aim (1): Facilitated Attention versus Impaired Disengagement: Chronometry to Threat Biases

As alluded to earlier, there is much debate, derived from inconsistencies across studies, as to whether biases reflect an early and automatic orienting towards threat or a later difficulty in disengaging from threat (Cisler, Bacon, & Williams, 2009; Koster, Verschuere, Crombez, & Van Damme, 2005; Weierich et al., 2008). The extent to which quicker responding to threatening stimuli, indexed by reduced reaction times, reflects early versus late threat biases remains unclear. A more precise understanding of the time course of attentional biases is a prerequisite for their successful reversal or elimination and can provide crucial information regarding the processing stage that treatment protocols, such as the attention bias modification task, must target.

For this purpose, the memory-guided orienting paradigm was administered across two studies, with the sole distinction of the inter-stimulus interval (ISI) duration (Chapter 3). The first study used a long ISI range of 750 to 1150 ms, while the ISI in the follow-up study was a fixed 200 ms. While previous studies have primarily manipulated stimuli durations (Koster, Crombez, Verschuere, & Houwer, 2004; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Salemink et al., 2007), a manipulation of ISI enables the investigation of how threat elicits prolonged distraction, even in its absence. This approach may be more ecologically valid as threat in real-world settings is often transient.

To complement these behavioural indices of the chronometry of attentional distortions to threat, a final study using electroencephalography (EEG) was conducted (Chapter 5). This study explored the neural underpinnings of early attentional capture by threat, which underlies distortions in subsequent orienting. Measures using reaction time indices are inherently plagued by confounds, such as the potential effects of emotional stimuli on response selection and execution (Armstrong & Olatunji, 2012). Grimshaw, Foster, and Corballis (2014) found a dissociation in the rapid selection of angry faces as indicated by the N2pc versus by RT-based markers of attentional biases, which may be attributable to the confounding effects intrinsic to RT indices. The high temporal resolution afforded by event-related potentials (ERPs) renders EEG a useful tool for unveiling the temporal dynamics of rapid early deployment of attention to threat. The EEG study presented in Chapter 5 explored the effects of fearful faces on the re-allocation of attention to a subsequent stimulus by measuring the N2pc component. Previous studies have provided support for the use of the N2pc to demonstrate rapid attentional selection of emotional faces, even when they were irrelevant to the task (Holmes, Bradley, Kragh Nielsen, & Mogg, 2009; Ikeda, Sugiura, & Hasegawa, 2013). In order to establish the initial efficacy of this paradigm in extracting threat-related temporal dynamics, the study was conducted in a sample of healthy young adults, without the consideration of anxiety. Thus, the study served as a pilot that, if successfully able to capture the temporal intricacies of threat distraction, can serve as a basis for future incorporation of anxiety as a variable. As it was important to avoid artefacts stemming from eye movements, the EEG paradigm did not incorporate memory cues and thus slightly deviated from the overall theme of preceding studies. However, despite this thematic deviation, the benefits of EEG enabled a temporally precise investigation of attentional allocation and distraction by threat and therefore provided an important complement to behavioural measures.

1.5.3 Secondary Aim (2): Modulations by Age

Anxiety is a multifaceted vulnerability and thus characterising anxiety-related attentional biases within a single framework may be inappropriate. Instead, it is crucial to consider the heterogeneity of the anxiety population and it is particularly important to explore anxiety in an older adult population, given the dearth of relevant research. Despite cognitive impairments developing in late adulthood, emotion regulation is refined in healthy older adults, leading to increased mood stability (Allard & Isaacowitz, 2008) and to a positivity bias in attentional processing (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000; Lee & Knight, 2009; Reed, Chan, & Mikels, 2014). This bias describes an augmented focus on positive information and an efficient dismissal of negative information (Barber, Opitz, Martins, Sakaki, & Mather, 2016; Mather & Carstensen, 2005). Yet, despite these age-related shifts in attentional patterns, anxiety is nonetheless prevalent in older adults (Green, Magee, Steiner, & Teachman, 2017). Given that age modulates attentional processing, it is a key feature to consider when investigating anxiety-related biases. Thus, the study presented in Chapter 4 was devoted to exploring attentional distortions by threat that mark anxiety in late adulthood, with the specific aim of understanding how the positivity bias potentially modulates these distortions. For this aim, the memory-guided orienting paradigm was administered to a sample of both low and high anxious older adults to ascertain whether the introduction of a threatening distractor would affect the recruitment of long-term memories to guide attention and, specifically, whether the positivity bias might act as a buffer against the typical threat biases in anxiety.

1.6 Summary

The aims of the research in this doctoral thesis were to explore the interaction between selective attention to threatening information and other drivers of attention. Widening the investigation of anxiety-related threat biases to include memory-based signals introduces an ecologically valid approach. Specifically, as both implicit and explicit spatial contextual memories can promote attentional selection to task-relevant information, it is important to consider how threat potentially interferes with the employment of these cues. Further, behavioural measures of attention to threat were complemented by the use of EEG, which boasts high temporal resolution and provides a precise marker of attentional allocation to threat. Finally, the inclusion of an anxious older adult sample recognises age-normative changes in both attention and memory and explores how these changes may modulate threat biases.

2 Anxiety-Related Threat Effects on Contextual Cueing

Contextual regularities facilitate visual search, decreasing search times within learned contexts, compared to novel contexts, termed the *contextual cueing effect*. In addition to these regularities, the emotional valence of to-be-attended stimuli guides attention: threatening stimuli attract attention, particularly in anxious individuals. The primary study investigated the degree to which trait anxiety modulated contextual learning when contexts contained socially relevant face stimuli displaying differing emotions. Faces depicting either fearful or neutral expressions were incorporated into the contextual cueing paradigm. Arrays contained a single female target surrounded by distracting male faces. This methodology was adopted following a pilot study that only varied the emotionality of the distractors, while maintaining a neutral target. While this approach allowed the effects of distracting threat to be clearly isolated, it created a confounding factor of enhanced salience of the neutral target in the context of fearful face distractors, compared to neutral face distractors. The primary study therefore matched the emotion of the target and distractors, creating arrays of all fearful faces and all neutral faces. Half of the spatial configurations were repeated over the course of experimental blocks, while the remaining half were novel. Both repeated and novel configurations contained either fearful faces or neutral faces. Thus, the manipulation of emotion was orthogonal to the context conditions. Results revealed contextual cueing effects but showed that these were moderated by individual difference in trait anxiety, with poorer contextual learning in individuals with higher levels of trait anxiety, independent of face emotion. These findings suggest that trait anxiety is marked by a reduced ability to extract regularities from complex contexts, at least those involving socially relevant stimuli.

2.1 Introduction

Regularities in the environment promote learning of covariation among objects. Contextual cueing studies have shown that this learning results in efficient attentional orienting to relevant information (Chun & Jiang, 1998). When target objects are embedded within repeated configurations of distracting items in visual-search arrays, target identification is significantly more efficient. Learned consistent spatial configurations naturally guide attention to target locations, even when the memory for these configurations remains implicit (Chun & Phelps, 1999; Jiang & Chun, 2001). The typical contextual cueing task requires participants to search for a target ‘T’ within an array of distracting ‘L’ stimuli presented in different orientations. Memory

of the target context is indexed by contrasting search times on 'repeated' arrays, which maintain a consistent spatial relationship between the target and surrounding distractors, with 'novel' arrays, which use novel spatial configurations. Relative to novel arrays, performance on repeated arrays show a benefit in search times – the *contextual cueing effect*.

In addition to regularities in the context within which visual search operates, the emotional character of to-be-attended stimuli has also been demonstrated to enhance both attention and memory. For example, emotionally significant information yields greater reported recall, and is paired with heightened correlated activity in the amygdala and hippocampus (Kensinger & Corkin, 2003, 2004). This *emotional enhancement effect* suggests strengthened memories for emotional, compared to neutral, information and has been documented across studies using various types of stimuli and indices of memory (Hamann, 2001). The root of the effect remains unclear, with emotion either strengthening contextual information or alternatively amplifying visual details within a scene (Kensinger, Garoff-Eaton, & Schacter, 2006). While some studies have demonstrated that greater recall for emotional stimuli extends to contextual information, such as the background screen colour (Doerksen & Shimamura, 2001), others have shown that efficient extraction of emotional material from contexts is accompanied by a neglect of peripheral non-emotional information (Kensinger, Garoff-Eaton, & Schacter, 2007). In this *central/peripheral trade-off*, an emotional stimulus strengthens the attentional focus on specific emotional stimulus features while diverting attention away from other stimulus dimensions. Although the mechanism remains unclear, the degree to which emotional content buttresses memory encoding must be considered in relation to the emotional state of the individual. While some studies have shown deleterious effects of stress and anxiety on memory encoding and retrieval of non-emotional information (De Quervain, Roozendaal, Nitsch, McGaugh, & Hock,

2000; Ikeda, Iwanaga, & Seiwa, 1996), corticosteroid memory enhancement has been observed for emotionally arousing information (Buchanan & Lovallo, 2001). Thus, the emotional valence of the stimuli modulates the degree to which the emotional state of the individual affects memory.

The contextual cueing task enables the manipulation of implicit memories to guide attention and therefore provides a useful platform for assessing whether anxiety is marked by learning-based cognitive biases for emotional information. While the contextual cueing effect has been extensively replicated using non-emotional stimuli (e.g., Geyer, Zehetleitner, & Müller, 2010; Yamaguchi & Harwood, 2015; Zellin, von Mühlenen, Müller, & Conci, 2013), the extent to which the introduction of socially relevant stimuli and emotion into contexts interacts with memory-guided attention remains unclear. Stimuli in our environment are oftentimes imbued with emotional significance, whereby they achieve prioritised access to attention and stronger memory consolidation. In the context of attention, threatening information in particular has been demonstrated to gain priority over neutral stimuli, in line with a biologically adaptive account (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2004; Öhman, Flykt, & Esteves, 2001; Vuilleumier, Armony, Driver, & Dolan, 2001). Moreover, the degree of attention-related prioritisation of threat is modulated by trait anxiety. Anxious individuals have been found to detect threatening information more readily and have been suggested to experience difficulty in disengaging from such threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, Verschuere, & Houwer, 2004; Koster, Verschuere, Crombez, & Van Damme, 2005; Yiend & Mathews, 2001). However, extant studies demonstrating attentional biases in anxiety do not examine the extent to which emotion biases learning, as they tap into attentional capture by emotional stimuli, primarily

within dot-probe tasks (Bar-Haim et al., 2007), rather than tapping into the effects of context and learning on attention.

In the current study, I develop an adaptation of the contextual cueing task using socially relevant, face stimuli in order to investigate how the introduction of threat-related information affects learning of contextual relationships and guides subsequent attention in individuals with varying levels of trait anxiety. The incorporation of threat into the contextual cueing paradigm allows for a unique examination of how the modulation of task performance evolves over time. Contextual learning of threatening information has not yet been thoroughly explored. In a study by Kunar, Watson, Cole, and Cox (2014), participants viewed negative and neutral stimuli prior to completion of the contextual cueing task developed by Chun and Jiang (1998). Results revealed a diminished contextual cueing effect subsequent to negative exposure, suggesting that negative stimuli narrowed the focus of attention, consequently reducing processing of the global context. Importantly, this interpretation of a threat-induced narrowing of attention contrasts with findings demonstrating a diffusion of attention in response to fearful faces. As threat signalled by fearful faces is inherently ambiguous, attention must be devoted to the broader context in order to establish its source (Taylor & Whalen, 2014). Moreover, as Kunar et al. (2014) introduced emotionality in the pre-exposure period, rather than during the task itself, their findings do not address how incorporating threat directly into contexts affects learning. Yamaguchi and Harwood (2015) instead incorporated threatening stimuli directly into the contextual cueing task, supplanting the typically used letters with images of spiders and mushrooms. In contrast to the study by Kunar et al. (2014), they found no effect of threat on contextual cueing, with comparable learning for threatening (spiders) and neutral (mushrooms) contexts. However, they did not assess participants' aversion to spiders (or mushrooms), which may show inter-individual

variability (Öhman et al., 2001; Weymar, Gerdes, Löw, Alpers, & Hamm, 2013). Instead, emotional faces naturally capture attention across individuals and are therefore more ecologically valid. Szekely, Rajaram, & Mohanty (2016) incorporated line drawings of neutral and angry faces into the contextual cueing task, requiring participants to detect a singleton dotted-line face. When arrays of threatening faces and arrays of non-threatening faces were interspersed, only contexts containing threatening faces elicited contextual learning. Instead contextual learning was reversed for arrays of non-threatening faces, such that RTs were greater for repeated, compared to novel, contexts. Such reversal was posited to result from an increase in vigilance to threat and a corresponding prepotent response to detecting threatening targets in familiar contexts, causing a slowing when targets were non-threatening. These findings thus suggest that the initial bottom-up salience of threatening faces is gradually supplanted by the learning of contexts containing threat and thus underscore the contribution of top-down processing in driving attentional capture of threat. Importantly, however, these studies incorporating threatening material into the cueing paradigm did not assess individual differences, and thus may have missed potential interactions with participants' emotional vulnerabilities.

Thus, the few studies devoted to exploring the role of threat on contextual learning leave room for further research. Learning consistencies in the environment enables enhanced detection through greater predictive power. Such learning is particularly adaptive when contexts contain threatening information, as it increases the predictability of future threat and thereby allows for quick responding (Yamaguchi & Harwood, 2015). My study builds on these initial explorations of how threatening material affects contextual learning in two ways. First, I directly incorporated fearful faces, which carry biological and social relevance that is common across individuals, into the contextual cueing task. The use of static coloured face photos provides an ecologically valid

approach (Ashley, Vuilleumier, & Swick, 2004; Eimer & Holmes, 2002; Eimer, Holmes, & McGlone, 2003). In particular, fearful faces, which signal impending threat, are rapidly processed so as to enable sufficient evaluation for an appropriate survival response (Öhman, 1993; Öhman & Mineka, 2001; Pourtois, Grandjean, Sander, & Vuilleumier, 2004). Second, I examined how individual differences in trait anxiety modulate the utilisation of contextual memories to guide performance. Using a sample of healthy individuals exhibiting a range of trait anxiety allows for generalisable results, informing how variations in anxiety in a non-clinical sample affect contextual learning. Given that studies examining contextual cueing often do not consider individual differences, results of the current study may be highly informative.

Overall, I predicted that, when searching for a target face, distracting fearful faces would cause a narrowing of attentional focus towards individual distractors, preventing processing of the global configuration. Distraction by fearful faces would result in longer RTs and would prevent efficient encoding of the spatial regularities of repeated arrays, thereby diminishing or entirely eliminating the contextual cueing effect in fearful contexts. I predicted that attentional narrowing in response to the fearful faces and the resulting impairment in contextual learning would be evident particularly or exclusively in participants with higher levels of trait anxiety.

The study was developed after a pilot study was conducted that used neutral and fearful faces as distractors, whilst using a consistently neutral target female face. While this manipulation allowed for the effects of task-irrelevant threat distraction to be isolated, it also created a confounding factor by inevitably enhancing the target salience in the fearful distractor condition. Thus, the primary study matched target and distractor emotion to explore the effects of overall emotion on contextual cueing.

2.2 Pilot Study

2.2.1 Methods

Participants

Thirty-two adults (mean age = 22.0; 14 females) were recruited through an online participant database and via emails to colleges of Oxford University. All participants were right-handed, had normal or corrected vision, had no history of neurological or psychiatric illness, and were fluent in English. Participants gave their written informed consent and were compensated £10/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC-C1-2014-075).

Procedure

Eligible participants were invited to attend the experimental session at the Department of Experimental Psychology at the University of Oxford. After giving informed consent, participants completed paper versions of the State-Trait Anxiety Inventory Trait-scale (STAI-T) questionnaire (Spielberger, 1983), the state subscale of the STAI, the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996) and the Neuroticism subscale of the Eysenck Personality Questionnaire (EPQ-N; Eysenck & Eysenck, 1975). Results of questionnaires are shown in Table 2-1. Participants then completed 30 blocks of the search task. Participants were provided with separate written instructions prior to the start of the task. Each block contained 48 trials, and breaks were provided between blocks. The study took approximately 1 hour in total.

STAI-trait	39.97 (± 1.62)	23–64
STAI-state	32.32 (± 1.50)	20–58
BDI-II	7.24 (± 1.12)	0–26
EPQN	4.79 (± 0.59)	0–10

Table 2-1: Questionnaire results. Means are shown with *SEM* in parentheses and range on the far right.

Search Task

The study developed a novel adaptation of the contextual cueing task, incorporating emotional faces, to be used in a sample of individuals with varying levels of trait anxiety. The task therefore preserves effortful target identification via the use of complex stimuli and the requirement of discriminating the sex of face stimuli.

Participants viewed successive arrays of face stimuli, and were asked to make a discrimination based on a single female (target) face with a neutral expression appearing amidst distracting male faces with either all neutral or all fearful expressions. Participants were told that the expressions of the faces were irrelevant to the task and therefore should be ignored. Participants were free to move their eyes.

Arrays consisted of 11 distracting male faces and a single target female face (Figure 2-1B). All faces had a black dot (‘mole’) located to the left or right of their mouths. Participants were shown an image of the target female face prior to starting the task (Figure 2-1A) and were

instructed to find the female face and indicate whether the mole was on the left or right with a corresponding mouse click.

Half of the arrays (24) were repeated once per block ('repeated'), while the remaining arrays were randomly generated on each trial ('novel'). The target location was fixed for each repeated configuration, thus rendering the configuration predictive of the target location but not predictive of the position of the mole on the target (i.e. the response). For both repeated and novel contexts, half of the trials contained arrays of fearful face distractors and the remaining trials contained arrays of neutral face distractors. Thus, context and emotion of arrays were manipulated orthogonally and factorially, yielding four conditions: novel fearful, novel neutral, repeated fearful, and repeated neutral. These conditions were divided equally within blocks and were presented in random order.

Arrays remained on the screen until responses were made, followed by an inter-trial interval (ITI) of 1000 ms. No feedback was provided. Reaction times were defined as the duration between the onset of the array and a mouse click. Participants completed the task in an enclosed booth, with dimmed lighting. They responded with their right hand and were instructed to respond quickly but with an emphasis on accuracy. Mandatory breaks of 10 seconds (or longer if participants requested) were taken after each block.

A

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B

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Figure 2-1: (A) Target female face depicting a neutral expression. (B) Examples of fearful (first image) and neutral (second image) arrays. The target female is circled here for illustration purposes.

Stimuli and Apparatus

The task was completed on a 1366 × 768 pixel Dell colour monitor using Presentation software (Neurobehavioral Systems, Albany, CA). The stimulus arrays, including stimulus placement, were generated using Matlab 9.0 (MathWorks) and were presented using Presentation 16.2.

Face stimuli were presented in black and white. They were taken, with permission, from the Amsterdam Dynamic Facial Expressions Set (ADFES; van der Schalk, Hawk, Fischer, & Doosje, 2011) and the Radboud Faces Database (RaFD; Langner et al., 2010). A standardised oval was used to crop the faces to ensure that they were of a standard size across trials. The oval was placed so as to include only the eyes, nose and mouth, part of the chin, and the hairline. A total of 48 faces of 12 male actors were used as distractors. Fearful and neutral faces of each actor were used, with the mole on the right and left side. A single female face was used as the neutral target.

All face stimuli were presented against a white background, and subtended 1.0° × 1.6° of the visual angle at a viewing distance of approximately 74 cm. Stimuli were presented within an 850 × 608 pixel area centred on the screen. This window was divided into a 6 × 8 matrix with 48 (2.5° × 2.5°of the visual angle) cells to guide placement of the stimuli. Faces were placed within the individual cells and were jittered horizontally and vertically in steps of 0.1° within a range of ±0.6°. For each participant, target locations were selected from 12 of 20 possible pre-determined locations. These locations were never in the centre or perimeter of the screen. Distractor locations were selected from the remaining non-target locations. The locations of distractor faces were fixed for repeated arrays. While the locations of moles on distractors were randomly generated on each trial, the location of the mole on the female target was counterbalanced across conditions such that half of the trials within each condition required right responses and the remaining half required left responses.

2.2.2 Analysis

The data were analysed using analyses of covariance (ANCOVA) and an alpha level of .05. Trait anxiety (STAI-T) scores were treated as a continuous predictor, and the experimental task factors were treated as within-subjects factors. Across analyses, where the assumption of sphericity was violated, degrees of freedom were adjusted using either Greenhouse-Geisser or Huynh-Feldt corrections; if $\varepsilon > 0.75$, a Huynh-Feldt correction was applied (Field, 2011; Girden, 1992). All post-hoc tests were conducted with Bonferroni correction for multiple comparisons.

The 30 blocks of the visual search task were divided into 6 epochs (i.e. each consisting of 5 blocks) in order to provide more stable measures, and thus facilitate statistical comparisons of

contextual cueing effects. Reaction times were analysed using a mixed-model ANCOVA, with context (repeated, novel), emotion (fearful, neutral), and epoch (1–6) as within-subjects factors and trait anxiety as the continuous predictor.

2.2.3 Results

Participants showed an adequate spread of STAI-T scores, ranging from 23 to 64, inclusive (M = 40.47, SD = 9.47) (Figure 2-2). The Shapiro-Wilk test revealed that the distribution of STAI-T scores did not diverge from normal (p = .94).

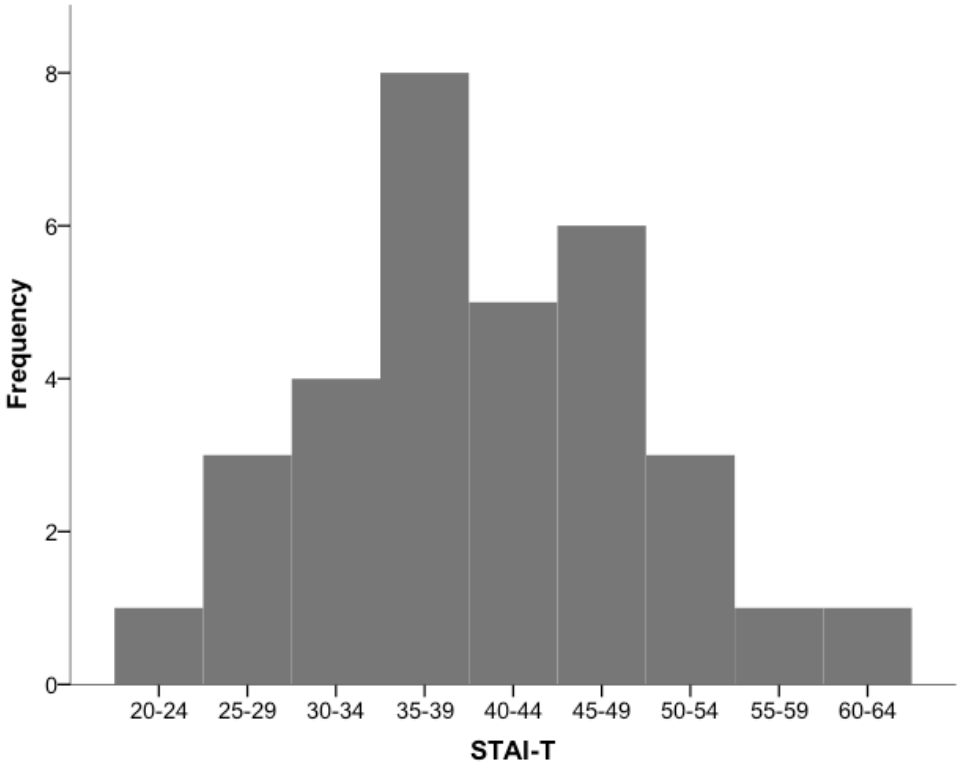

Figure 2-2: The spread of STAI-trait scores.

Search Task

Search times and accuracy were recorded. Search times were the primary dependent variable of interest. As expected, accuracy was high overall (99.99%). Analysis of RTs was confined to trials with correct responses. Trials with errors were removed for subsequent analyses (1.5%). Trials for which RTs were less than or exceeded 3 standard deviations of individual means for each epoch were also removed (1.6%).

A 2 × 2 × 6 mixed-design ANCOVA was conducted on accuracy with context, emotion, and epoch as within-subjects factors and anxiety as the continuous predictor. Results did not reveal any main effects or interactions (all p's > .77).

Results of the ANCOVA on averaged RTs revealed a significant main effect of context [F (1, 30) = 7.17, p = .012, η_p^2 = .19], with reduced RTs for repeated contexts (M = 1762.15 ms, ± SEM = 37.74) compared to novel contexts (M = 1804.26 ± SEM = 38.91). The interaction with epoch was only marginally significant at the two-tailed level [F (5, 150) = 2.01, p = .083]. Moreover, results revealed an interaction between context, emotion, and STAI-T [F (1, 30) = 12.80, p = .001, η_p^2 = .30]. To understand this interaction, correlations were computed between STAI-T and the difference in search times for repeated and novel contexts, separately for fearful and for neutral distractor conditions. These differences were normalised against the average search time for each distractor condition. As there was no interaction between context and epoch, the search time differences were computed across epochs. This revealed a significant negative correlation between STAI-T and the normalised difference in search times between contexts in the fearful condition [r = -.60, p < .001]. The correlation for the neutral condition was not significant [r = .21, p = .23] (Figure 2-3B).

Separate additional ANCOVAs were conducted using STAI-state, BDI, and EPQN scores. The Shapiro-Wilk test revealed that STAI-state scores and BDI scores showed a non-normal, positive-skewed distribution (p = .025 for the STAI-state; p = .001 for the BDI). Thus, log transformations were conducted, resulting in normal distributions (p = .40 for the STAI-state; p = .42 for the BDI). Results revealed an interaction between context, emotion, and EPQN [F (1, 30) = 6.04, p = .020, η_p^2 = .17] and a marginally significant interaction between context, emotion, and BDI [F (1, 30) = 3.49, p = .071, η_p^2 = .10], thus revealing modulations by neuroticism and depression levels that were similar to those by trait anxiety. The interaction was not significant for STAI-state scores [F (1, 30) = 0.22, p = .65].

The lacking interaction between context and epoch may be due to the rapid learning that quickly plateaued, with the minimal variation across epochs hindering the emergence of an interaction in analyses. As Figure 2-3A shows, contextual learning occurred as early as the second epoch. In particular, search times of repeated and novel contexts were not significantly different at Epoch 1 [t (31) = 0.97, p = .34]. However, repeated and novel contexts yielded significantly different search times at Epoch 2 [t (31) = 4.30, p < .001]. Thus, the lack of a context × epoch interaction may not indicate a lack of contextual learning but may instead reflect rapid learning acquired early in the task, precluding further increases in learning across epochs. Alternatively, results may have been driven by learning of the identical singleton target used across trials, encouraging reliance on bottom-up salience signals in guiding attention. Such salience would be particularly evident in arrays of fearful face distractors, in which the neutral face target is perceptually distinctive. This explanation is corroborated by evidence of reduced RTs to arrays of fearful face distractors (M = 1728.38 ms ± SEM = 38.74), compared to arrays of neutral face distractors (M = 1838.03 ms ± SEM = 39.95) [t (31) = -6.98, p < .001, d = 1.23, CI =

(-141.69, -77.60)]. These methodological confounds, which may have contributed to the lacking interaction, will be discussed below.

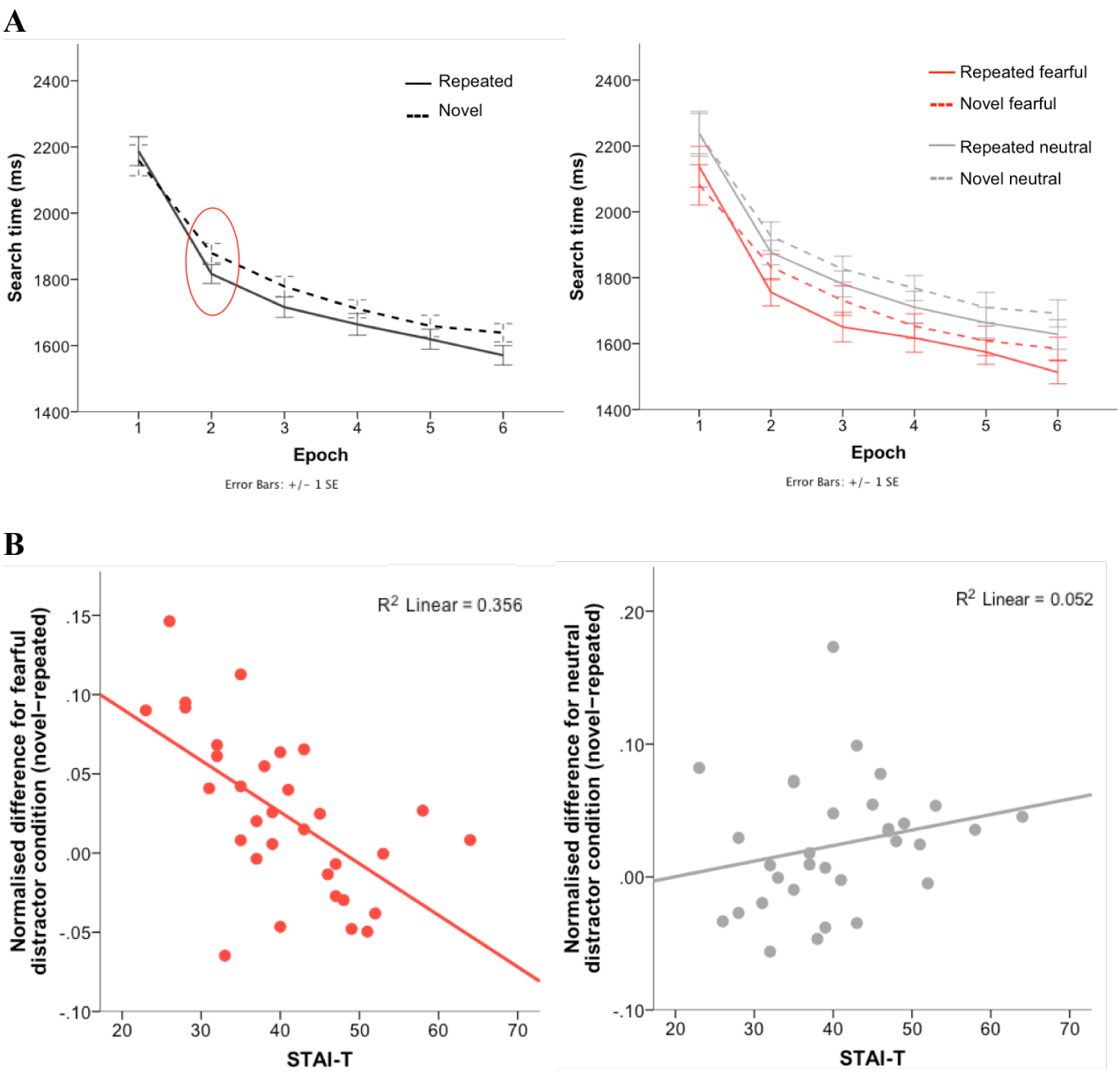

Figure 2-3: (A) The contextual cueing effect is shown by the difference in search times for repeated contexts (solid line) and novel contexts (dotted line) over the course of the six experimental epochs. A significant difference between contexts emerged at Epoch 2, circled in red (left). The contextual cueing effect is shown separately for each emotion condition. Red lines depict arrays of fearful faces and grey lines depict arrays of neutral faces (right). (B) Significant negative correlation between STAI-T (*x*-axis) and the normalised difference in search times between repeated and novel arrays for arrays containing fearful face distractors (*y*-axis) (left) and non-significant correlation for arrays containing neutral face distractors (right), across epochs.

2.2.4 Interim Discussion

The set of results shows that arrays containing fearful face distractors impaired the ability to extract regularities as a function of trait anxiety. This was indexed by a reduced difference between RTs for novel and repeated arrays in participants with high levels of trait anxiety.

Unlike most results in contextual cueing studies, the interaction between context and epoch did not reach significance in the current experiment. The lack of interaction may be due to the early emergence of contextual learning, which subsequently remained constant across epochs. In addition, or alternatively, methodological constraints may have promoted bottom-up attentional guidance. The manipulation of distractor emotion with a fixed target allowed the effects of valenced task-irrelevant information on contextual learning to be isolated. However, the use of a target, whose identity and expression remained constant, may have had two undesirable effects that may have interfered with contextual learning. First, the fixed female face may have promoted learning to detect a constant singleton, rather than contextual learning per se, and thereby created comparable learning slopes for both repeated and novel contexts across epochs. Second, a confounding factor arises by virtue of the target's greater perceptual distinction from distractors in the fearful face condition, thus heightening its bottom-up salience, and potentially explaining the relatively rapid learning of arrays containing fearful faces, particularly in low anxious participants. The singleton search resulting from the distinctive target incites a competition between bottom-up salience and top-down memory cues. That is, target selection may be driven primarily by bottom-up signals, thereby obscuring contextual cueing.

To overcome these limitations, the primary study matched the target's emotion to the surrounding distractors, creating arrays of all fearful faces and arrays of all neutral faces. Additionally, two further modifications were made. First, as previous studies have posited that

contextual cueing is based on implicit learning by showing participants' lack of explicit awareness of repeated arrays, the degree to which contextual learning operates implicitly was assessed using an incidental recognition task. Second, contextual cueing has consistently been quantified using RT data. However, the extent to which learned regularities facilitates perceptual sensitivity remains unclear. Thus, a single exploratory block was included in which contextual learning was assessed using *d'*, an index of perceptual sensitivity.

2.3 Primary Experiment

2.3.1 Methods

Participants

Fifty adults, aged 18 to 33 years (mean age = 23.72, *SD* = 4.04; 34 females), were recruited through an online participant database. Participants were recruited based on their STAI-T (Spielberger, 1983) scores so as to ensure an adequate spread of trait anxiety levels. In particular, cut-off scores of 40 were used to distinguish between low and high anxiety levels, with scores of 40 and above signifying high anxiety. Recruitment was aimed at ensuring a spread of scores by obtaining equal numbers of participants in high and low anxious groups.

All participants were right-handed, had normal or corrected vision, had no history of neurological or psychiatric illness, and were fluent in English. Participants gave their written informed consent and were compensated £10/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC-C1-2014-075).

Procedure

Participants who met pre-screening criteria for trait anxiety, as described above, were invited to attend the experimental session at the Department of Experimental Psychology at the University of Oxford. After giving informed consent, participants completed the STAI-T for a second time on the online questionnaire platform Qualtrics (Qualtrics, Provo, UT). While pre-screening scores were used to ensure an adequate STAI-T range, scores obtained on the day of the experiment were used for analyses. Participants also completed the STAI-state, the BDI, and the EPQN. Results of questionnaires are shown in Table 2-2. Participants then completed two tasks, in the following order: search task (30 blocks), detection task (1 block), and recognition test (1 block). Participants were provided with separate written instructions prior to the start of each task. Each block contained 48 trials, and breaks were provided between blocks. The study took approximately 1.5 hours in total.

STAI-trait	38.92 (± 1.58)	21–65
STAI-state	31.80 (± 1.32)	21–58
BDI-II	6.64 (± 1.12)	0–35
EPQN	3.76 (± 0.45)	0–11

Table 2-2: Questionnaire results. Means are shown with *SEM* in parentheses and range on the far right.

Search Task

The search task was identical to that in the pilot study, with the crucial change of matching the emotional expression of the target female to the expressions of the distractor faces, depicting either fearful or neutral expressions (Figure 2-4A). Thus, arrays consisted of either all fearful faces or all neutral faces (Figure 2-4B).

A

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Figure 2-4: (A) Target female face depicting fearful (left) and neutral (right) expressions. (B) Examples of fearful (first image) and neutral (second image) arrays. The target female is circled here for illustration purposes.

Detection Task

After the search task, participants completed a novel adaptation of the search task designed to test whether contextual cueing can affect perceptual sensitivity. Participants viewed repeated or novel arrays with fearful or neutral faces for a time-limited period of 1000 ms, followed by a 1000 ms ITI, and had to make a judgment as to whether the target female face was present or absent. The

female target face was present on half the trials; on the other half of trials, the female target was replaced by a male face.[5] Participants indicated whether the female face was present or absent by using left or right mouse clicks, respectively. Participants completed one block of 48 trials.

Recognition Task

In order to test for explicit awareness of repeated arrays, an incidental recognition test was delivered at the conclusion of the testing session. In the recognition task, repeated arrays from the previous tasks and entirely novel arrays were presented (24 trials each).[6] Participants were asked to indicate, at an unspeeded pace, whether they thought each array had been presented during the experiment, with a yes/no response. Arrays remained on the screen until responses were made.

2.3.2 Analysis

The data were analysed using analyses of covariance (ANCOVA). Trait anxiety (STAI-T) scores were treated as a continuous predictor, and the experimental task factors were treated as within-subjects factors. Across analyses, where the assumption of sphericity was violated, degrees of freedom were adjusted using either Greenhouse-Geisser or Huynh-Feldt corrections; if $\varepsilon > 0.75$, a Huynh-Feldt correction was applied (Field, 2011; Girden, 1992). All post-hoc tests were conducted with Bonferroni correction for multiple comparisons.

[5] Context × emotion conditions were counterbalanced across present/absent trials. That is, for trials in which the target was present/absent, half of the trials showed previously repeated arrays, with a further half of these trials presenting fearful face arrays.

[6] Half of the repeated arrays and half of the entirely novel arrays contained fearful faces, while the remaining half contained neutral faces.

As was done in the pilot study, the 30 blocks of the visual search task were divided into 6 epochs. Reaction times were analysed using two complementary ANCOVAs: one using averaged RTs within epochs and the other using learning slopes over the epochs.

In the first set of analyses, comparable to analyses in the pilot study, a mixed-model ANCOVA was conducted, with context (repeated, novel), emotion (fearful, neutral), and epoch (1–6) as within-subjects factors and trait anxiety as the continuous predictor. In the second set of analyses, learning-slope parameters were estimated using power-law functions that were fit to the RT data. For this, I fit RT data for the 'repeated neutral' condition (i.e. repeated arrays containing neutral faces) to exponential, power-law, and linear models and used mean square error to ascertain the best fitting model. I did this using data from only this condition as it is devoid of emotionality and thus best mimics the repeated arrays used in previous studies. The power-law function has been used effectively in various cognitive and motor learning tasks, with strong initial practice-related performance gains that gradually plateau (Newell & Rosenbloom, 1981; Palmeri, 1999). The function takes the form:

$$RT = a + bP^{-c}$$

where RT is reaction time, P is the trial number, constant a reflects the asymptote of learning, constant b represents the difference between initial and asymptotic performance, and exponent c is the learning rate. These slopes were entered into an ANCOVA, with context and emotion as within-subjects factors and trait anxiety as the continuous predictor.

2.3.3 Results

In accordance with the recruitment strategy, participants had an adequate spread of STAI-T scores, ranging from 21 to 65, inclusive (M = 38.92, SD = 11.15) The Shapiro-Wilk test revealed that the distribution of STAI-T scores did not diverge significantly from normal (p = .12) (Figure 2-5).

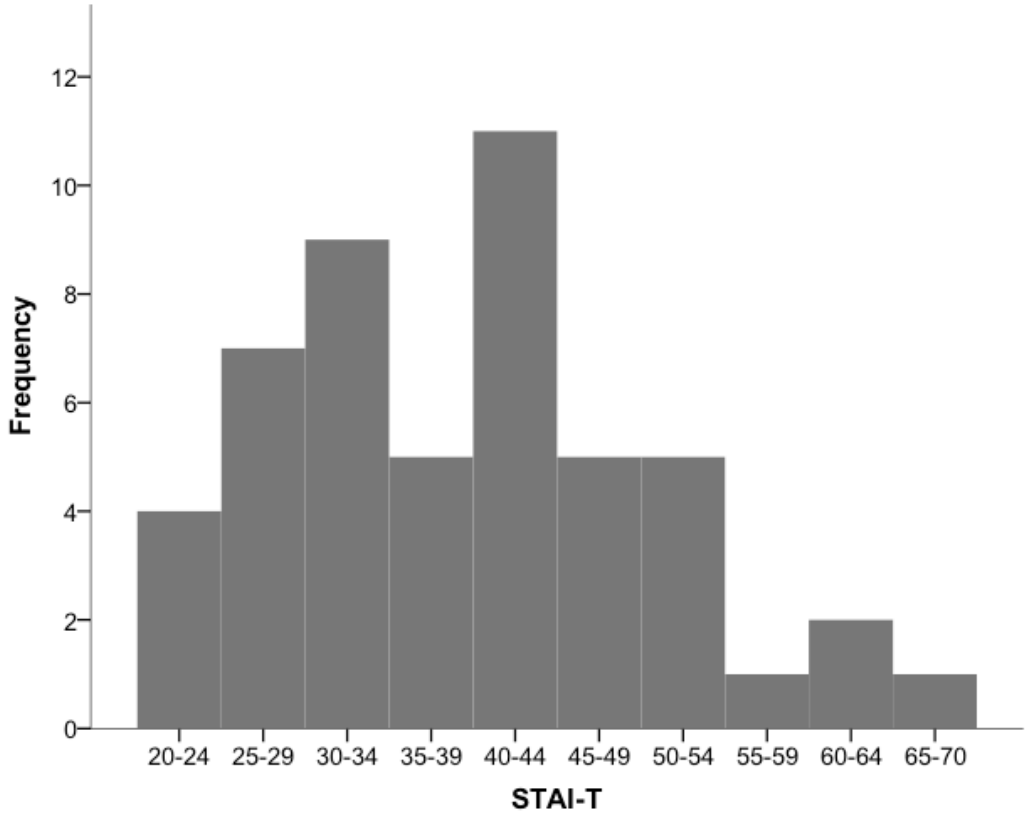


Figure 2-5: The spread of STAI-trait scores.

Search Task

Search times and accuracy were recorded. Search times were the primary dependent variable of interest. As expected, accuracy was high overall (98.2%). The ANCOVA revealed no significant

main effects or interactions involving context, emotion, or epoch on accuracy, and no interactions with STAI-T (all p's > .38).

Analysis of RTs was confined to trials with correct responses. Trials with errors were removed for subsequent analyses (1.8%). Trials for which RTs were less than or exceeded 3 standard deviations of individual means for each epoch were also removed (0.9%).

The first ANCOVA on averaged RTs revealed a significant interaction between context and epoch [F (4.53, 217.54) = 3.32, p = .009, η_p^2 = .07],[7] indexing a contextual cueing effect (Figure 2-6). Importantly, this was qualified by a significant interaction between context, epoch, and STAI-T [F (4.53, 217.54) = 2.48, p = .038, η_p^2 = .05]. There was no significant main effect of emotion and no additional significant interactions with emotion (all p's > .19). To clarify and visualise the significant interaction, a high anxious and a low anxious group were created using a median split of STAI-T scores (median = 39.0). ANOVAs were conducted separately for these two groups, with within-subjects factors of context, emotion, and epoch, and revealed that only the low anxious group showed a significant context × epoch interaction [F (3.9, 91.93) = 4.29, p = .004, η_p^2 = .15],[8] while the high anxious group did not [F (4.2, 101.16) = 1.53, p = 0.20].[9] These findings therefore suggest that contextual learning was restricted to low anxious participants.

The second ANCOVA used slopes derived from the power-law function. It should be noted, however, that the fearful face conditions (both repeated and novel) showed a better fit

[7] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (14) = 29.59, p = .009. Huynh-Feldt correction was applied (ε = 0.88). Corrections were applied to interactions with trait anxiety.
[8] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (14) = 29.42, p = .009. Huynh-Feldt correction was applied (ε = 0.77). Corrections were applied to interactions with trait anxiety.
[9] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (14) = 29.54, p = .009. Huynh-Feldt correction was applied (ε = 0.84). Corrections were applied to interactions with trait anxiety.

using the linear model, across participants. However, in line with previous contextual cueing studies (Chun & Jiang, 2003) and in order to enable comparisons between emotion conditions, the power-law function was used to fit RTs for all conditions. Importantly, the overall mean square error for the power-law function was significantly smaller (*MSE* = 117097.40) than that for the linear model (*MSE* = 131570.50) [t (50) = 6.05, $p < .001$, d = 0.85, CI = (9665.13, 19281.08)]. Results of the ANCOVA revealed a significant main effect of context [F (1, 48) = 15.03, $p < .001$, $\eta_p^2 = .24$], with repeated arrays showing a steeper slope (M = -0.15 ± SEM = 0.007) compared to novel arrays (M = -0.13 ± SEM = 0.006). These results therefore provide evidence of contextual cueing. The main effect of context was qualified by a significant interaction with STAI-T [F (1, 48) = 4.73, p = .006, $\eta_p^2 = .15$]. To clarify this interaction, the correlation between STAI-T and the difference in slopes between novel and repeated contexts (i.e. contextual learning), normalised against the average slope across context conditions, was computed. Results revealed a significant positive correlation [r = .38, p = .006], showing that the contextual cueing effect was reduced with greater STAI-T scores (Figure 2-7).[10]

Finally, separate additional ANCOVAs were conducted on slopes using STAI-state, BDI, and EPQN scores. The Shapiro-Wilk test revealed that scores from all questionnaires showed a non-normal distribution ($p < .001$ for the STAI-state; $p < .001$ for the BDI; p = .002 for the EPQN). Log transformations failed to normalise scores (p = .024 for the STAI-state; p = .015 for the BDI; p = .010 for the EPQN). Thus non-parametric Mann-Whitney U tests were conducted using high- and low-scoring groups based on median splits (medians: STAI-state = 29.5; BDI =

[10] To clarify, the difference in slopes between contexts (novel–repeated) was positive, as the slopes for both conditions were negative, with those for repeated arrays being steeper. However, as normalising was achieved by dividing by the average slope, which was negative, the normalised difference became negative. Thus, a negative value indicates contextual learning and therefore the positive correlation with STAI-T reflects poorer contextual learning at higher levels of trait anxiety. Without normalising the difference, a positive value reflects learning and correlations with STAI-T become negative [r = -.39, p = .006].

4.5; EPQN = 3.0). Results revealed a significant difference in slopes for the novel, neutral condition between high- and low state anxious groups [U = 182.0, p = .011] and between high- and low-depressed groups [U = 197.0, p = 0.025], with the high state anxious group and the high-depressed group showing steeper slopes (M = -0.15 ± SEM = 0.008; M = -0.15 ± SEM = 0.01). Results for the EPQN revealed no differences between groups (all p's > .17).

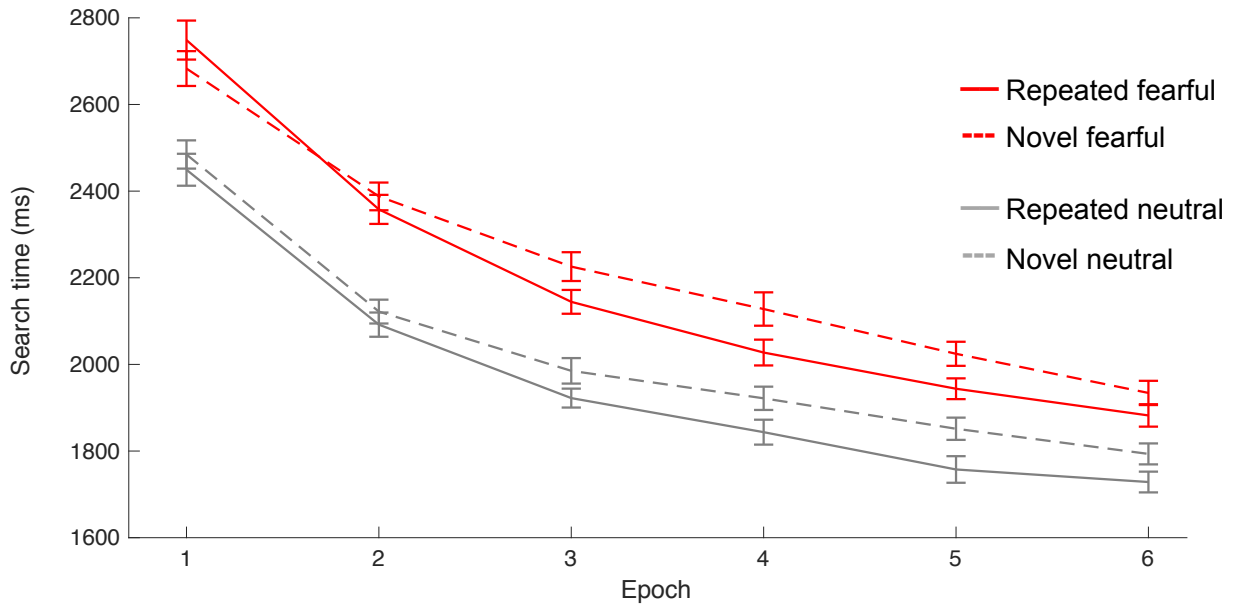


Figure 2-6: The contextual cueing effect is shown by the difference in search times for repeated contexts (solid lines) and novel contexts (dotted lines) over the course of the six experimental epochs. Red lines depict arrays of fearful faces and grey lines depict arrays of neutral faces. The significant context × epoch interaction, i.e. the contextual cueing effect, was not qualified by an interaction with emotion.

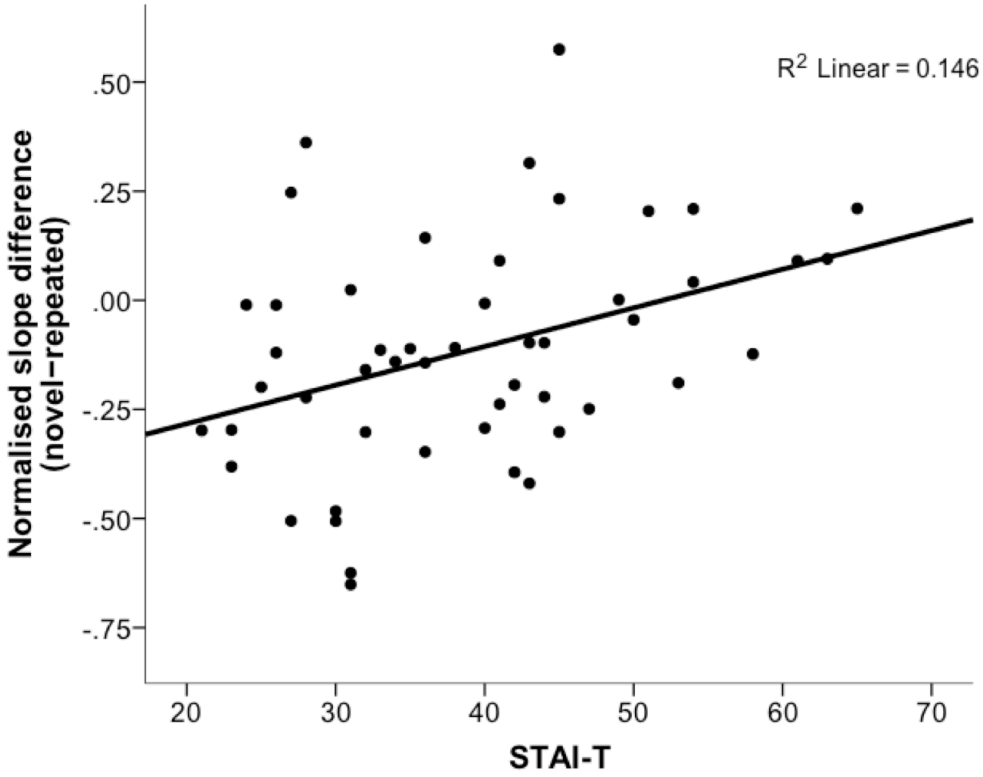


Figure 2-7: Significant positive correlation between STAI-T (*x*-axis) and the normalised difference in slopes between novel and repeated contexts, across emotion (*y*-axis). The difference was normalised using the average slope across conditions.

Detection Task

The detection task was analysed using d' with the following formula (Macmillan, 2002):

$$d' = z(\text{hits}) - z(\text{false alarms})$$

Participants whose average accuracy was at or below 50% were removed from further analyses. This resulted in the removal of three participants. The average d' of the remaining participants was 1.28 (± *SEM* = 0.06). The range of values was high (1.72: (0.54–2.26)), indicating high inter-individual variability.

A 2 × 2 mixed-design ANCOVA using *d′* scores was conducted with context and emotion as the within-subjects factors and STAI-T as the continuous predictor. Results revealed no main effects or interactions (all p's > .16).

Recognition Task

Overall, recognition accuracy was 49.41%. Participants correctly reported previously repeated contexts as having been presented in the previous search task on 52.50% of trials (i.e. hits) and incorrectly reported that entirely novel contexts were presented in the previous search task on 53.67% of trials (i.e. false alarms). Importantly, paired-samples *t* tests revealed no significant difference between accuracy for repeated and entirely novel arrays [t (49) = 1.48, p = .15]. These results indicate that participants were not aware of the configural repetitions, lending support to the interpretation that contextual cueing relied on implicit memory in our task (Chun & Jiang, 1998; Zellin et al., 2013).

To assess whether recognition differed according to context, emotion, or anxiety level, a 2 × 2 mixed-design ANCOVA using recognition accuracy was conducted with context and emotion as the within-subjects factors and STAI-T as the continuous predictor. Results revealed no significant main effects or interactions (all p's > .26).

2.4 Discussion

The current study introduced an adapted version of the contextual cueing paradigm incorporating emotional faces. A pilot study was conducted that isolated emotional distraction from target detection to examine how task-irrelevant threat salience interacts with contextual cueing.

However, due to the aforementioned resulting confounds, the primary study matched the depicted emotions of target and distractors, thereby circumventing the confounding variables. This discussion will therefore focus only on the primary study.

First, results of the study showed that it was possible to elicit contextual cueing with complex, socially relevant stimuli, suggesting an ingrained ability to extract contextual regularities to guide attention. These findings add to the limited extant literature using threatening stimuli in the contextual cueing task (Kunar et al., 2014; Szekely et al., 2016; Yamaguchi & Harwood, 2015). Furthermore, the use of photographs depicting emotional faces introduces a novel and ecologically valid approach to investigating the effects of salient threat on cueing. Given that the inherent salience of faces depicting fear taps into the biases to threatening information that mark anxiety, the incorporation of fearful faces provides a robust account of potential anxiety-related biases in implicit learning of contexts containing threat.

Strikingly, results revealed that trait anxiety within a healthy participant population modulated the ability to learn regularities of contexts containing faces in order to guide adaptive behaviour. Both measures of contextual cueing effects, i.e. RTs over epochs and slopes, demonstrated an adverse effect of anxiety on contextual cueing. The modulation of contextual cueing by trait anxiety underscores the importance of considering individual differences when examining learning and memory, and their consequence for future behaviour. Moreover, these findings expand our understanding of attentional biases in anxiety, in particular revealing deficits in extracting or utilising environmental regularities to guide behaviour in the context of socially relevant or affective stimulation. Interestingly, and contrary to my initial hypothesis, the anxiety-related impairments on contextual cueing operated independently of emotion of the faces.

The inability of anxious participants to extract contextual regularities may be attributable to excessive attentional resources devoted to individual faces, causing a narrowing of attention. Such narrowed focus consequently prevented processing of the global context and thereby precluded learning of spatial regularities between target and distractor items. Previous studies have demonstrated that viewing emotional stimuli results in greater local, over global, processing (Gable & Harmon-Jones, 2010). The constriction of attention is suggested to stem from depleted attentional resources for processing peripheral information due to excessive focus on negative stimuli (Kunar et al., 2014).

However, contrary to my predictions, current results showed that emotional valence did not modulate the contextual learning impairment in anxious participants. In particular, the observed anxiety-related impairment was not accentuated in or limited to arrays containing fearful faces. Instead, participants with high anxiety exhibited difficulty in extracting regularities from contexts of all face stimuli, independent of emotion. Thus, these findings depart from previous accounts linking a narrowing of attention only to expressly negative material (Kunar et al., 2014). Moreover, current results also contrast with the established phenomenon of anxiety-related attentional biases to specifically threatening information (Bar-Haim et al., 2007). Studies employing visual search tasks in anxious participants have evidenced increased response times when distracting faces were threatening, signifying an inability to readily shift attention away from threat (Byrne & Eysenck, 1995; Gilboa-Schechtman, Foa, & Amir, 1999).

The absence of emotion modulations, and the corresponding departure from previous findings, may have two plausible explanations with regards to the deficient learning in the high anxious participants. First, although I used neutral faces, the social significance inherent to all faces may render them intrinsically emotional. Within this interpretation, current results suggest

that the emotionality conveyed by all faces captured attention in anxious participants such that attention was focused to individual items. This explanation is similar to the emotionality hypothesis, which postulates that anxious individuals allocate more attention to stimuli depicting any emotion, rather than specifically to material denoting threat (Calvo & Avero, 2005; Martin, Williams, & Clark, 1991).

Alternatively, the overall disruption of learning, independent of emotion, may be attributable to an interpretation bias that is commonly symptomatic of anxiety disorders and is characterised by a predilection to interpret ambiguous information in a negative manner (Eysenck, Mogg, May, Richards, & Mathews, 1991; Hirsch & Mathews, 1997). Although the neutral faces were intended to be devoid of emotion, they nonetheless bear an intrinsic ambiguity, as their emotionality is indiscernible and vague. The unexpected learning impairment caused by neutral faces may therefore result from anxious participants having disambiguated their neutrality in a negative fashion. The resulting negative valence bestowed on the faces consequently rendered them equally distracting as their fearful counterparts, leading to the observed overall impairment in learning. Research has demonstrated this linkage between attention and interpretation biases, with initial attention towards threatening information transferring to subsequent disambiguation of neutral material in a negative direction (White, Suway, Pine, Bar-Haim, & Fox, 2011). Greater attentional resources devoted to threatening stimuli affords them salience, thereby making negative interpretations highly accessible (Amir, Bomyea, & Beard, 2010). As arrays of fearful faces and those of neutral faces were interspersed, the threatening arrays may have set in motion the formulation of negative interpretations; thus, when faced with ambiguous neutral faces, anxious participants interpreted them as negative. The resulting overall negative valence of all faces could, therefore, have caused an inability to derive contextual

regularities. This possibility therefore renders the current results in fact compatible with previous accounts of anxiety-related threat biases.

To assess whether the non-blocked design indeed contributed to the overall disruption, trials with neutral face arrays were categorised into those directly preceded by fearful face arrays and those preceded by neutral face arrays, which will be referred to as 'previous fearful' and 'previous neutral' arrays, respectively. A paired samples *t* test was conducted on RTs using these new categorisations and revealed a significant difference in RTs between previous fearful and previous neutral arrays [t (49) = -3.40, p = .001, d = 0.48, CI = (-204.01, -52.43)], with previous fearful arrays showing increased RTs (M = 2528.17 ms ± SEM = 58.79) compared to previous neutral arrays (M = 2399.95 ms ± SEM = 51.99). These results suggest that there was indeed a carryover of disruption from the fearful face arrays to the neutral face arrays. To quantify this carryover, I computed an 'engagement index' as the difference in RTs between the previous fearful and previous neutral arrays, i.e. the extent to which threat disruption carried over into the neutral face array trials. Correlations were thereafter computed between the engagement index and the contextual cueing effect, both across emotion conditions and solely for the neutral face arrays trials. This yielded no significant correlation (p = .53 for overall cueing and p = .11 for the neutral condition). Moreover, the index did not significantly correlate with STAI-T (p = .59). Thus, while the distraction caused by arrays of fearful faces carried over into neighbouring neutral face array trials, the lack of correlation with both contextual learning and with trait anxiety suggest that the interspersing of fearful face arrays and neutral face arrays cannot explain the current set of results. However, although the non-blocked design may not have driven current results, I cannot rule out that anxious participants were indeed biased in interpreting the ambiguity of the neutral faces in a negative fashion.

Importantly, as a non-clinical sample was used, the current set of results reveals the variability in contextual learning as a function of individual differences. This is especially informative to future studies investigating contextual cueing by demonstrating the importance of taking these normal variations into account in order to obtain an ecologically valid and robust account of contextual learning.

It remains unclear whether the anxiety-related distraction of all faces observed in this study is best explained by the inherent emotionality stemming from the social significance of faces, and the related emotionality hypothesis, or alternatively by an interpretation bias that rendered all stimuli threatening. Future studies that incorporate non-facial stimuli are required in order to ascertain whether anxiety is marked by a difficulty in extracting regularities from all contexts or whether such difficulty is limited to contexts containing faces and other socially or emotionally salient stimuli.

Nonetheless, results reveal an overall disruption in contextual learning of face configurations in anxious individuals. Importantly, however, results did not reveal a main effect of anxiety level, indicating that while anxiety affected the ability to extract contextual information, it did not affect speed of target detection overall. This implies that the faces did not cause a typical anxiety-related difficulty in disengagement from threat (Koster, Crombez, Verschuere, et al., 2004; Salemink, Hout, & Kindt, 2007).

The impaired learning in participants with high levels of trait anxiety contrasts with the intact learning displayed by participants with lower trait anxiety scores. These results corroborate those of Yamaguchi and Harwood (2015), who found no evidence of threat effects on contextual cueing in healthy participants. The authors postulated that the threatening stimuli incorporated in the cueing paradigm might have caused rapid shifts of attention such that target detection

occurred prior to attentional narrowing, thereby forestalling threat-induced negative emotionality and corresponding adverse effects on cueing. Thus, in comparison to their high anxious counterparts, low anxious participants may possess greater immunity to attention narrowing by faces and instead experience the diffusion of attention necessary to extract contextual regularities. Although corroborating previous findings, the current study nevertheless underscores the importance of considering individual differences. Moreover, the lack of overall emotion effects in low anxious participants suggests that negative emotionality did not affect response speed. Fear-related stimuli have been shown to decrease reaction times in non-anxious individuals (Fox, Griggs, & Mouchlianitis, 2007; Öhman et al., 2001) due to a threat-induced increase in arousal and subsequent vigilance (Phelps & LeDoux, 2005). Olatunji et al. (2011) demonstrated that exposure to fearful faces prior to a non-emotional visual search task improved search efficiency. However, an important distinction between these studies and the current study is the quality of the search process. The targets used in previous studies may have been endowed with greater salience owing to distinctive physical properties or unique emotional valence, e.g. a singleton red circle (Olatunji et al., 2011). Such salience therefore laid the groundwork for efficient bottom-up target detection, with fearful stimuli simply supporting search processes for an already activated target. Instead, the increased task difficulty of the inefficient search intrinsic to the contextual cueing paradigm may preclude any search benefit via fear arousal mechanisms. These findings are corroborated by those of Kunar et al. (2014), which similarly showed no effect of threat exposure on overall response times in the contextual cueing paradigm in non-anxious participants.

The null results in the accuracy test indicate that contextual cueing effects were not mirrored in perceptual sensitivity. However, importantly, only a single block was included to

obtain an initial gauge of task efficacy. The addition of further blocks would provide a more robust investigation of the extent to which contextual learning translates into a sensitivity measure.

The recognition test overall revealed no awareness of the repetition of arrays, thereby suggesting that contextual cueing operates implicitly. This implicit nature of contextual learning is advantageous, as circumventing conscious awareness allows for the intake of more rich and complex contextual information that can more readily be learned and employed (Lewicki, Hill, & Bizot, 1988). The current results complement studies using explicit forms of contextual learning, which show that memories of contextual cues facilitate target detection (Patai et al., 2012; Summerfield et al., 2006, 2011). Taken together, these results suggest that guidance of attention can be achieved using both implicit and explicit contextual memories. It should be noted, however, that the recognition task in the current study consisted of only a single block in order to curb experimental duration. The small number of trials limited statistical power, and thus results from these tasks must be interpreted with caution.

Finally, while the power-law function was used to fit raw data across conditions, a linear model showed a better fit for the fearful face conditions, thus suggesting that learning patterns may differ as a function of stimulus emotion. The discrepancies in fit suggest that practice effects underlying the power-law function may take longer to manifest when stimuli depict threat, potentially on account of prolonged attentional capture of emotional faces (Koster, Crombez, Van Damme, et al., 2004). Additional blocks are required to ascertain the degree of delay in reaching asymptote for the fearful face trials.

There are some limitations to the study. First, the use of arrays of isolated faces lacks ecological validity, as real threat is encountered within naturally structured and complex

environments. However, I aimed to follow closely the original contextual cueing paradigm (Chun & Jiang, 1998) so as to understand whether a comparable cueing effect would be elicited when increasing the complexity of the stimuli (i.e. by using valenced faces). Moreover, the presentation of faces in the absence of real-world contextual information eliminated any potential engagement of prior knowledge, and thus rendered stimuli similar in terms of familiarity and salience. Thus, although lacking a realistic quality, the current task allows for a controlled investigation of threat effects on contextual processing. Second, as alluded to earlier, the sole use of face stimuli cannot address the extent to which contextual learning is impaired in high trait anxious individuals, i.e. whether the impairment is restricted to contexts containing social information or whether it extends to other stimuli.

These limitations notwithstanding, the current study underscores the strength of salient social stimuli in narrowing attention[11] and thereby impairing learning of global contexts as a function of individual differences in trait anxiety.

[11] As mentioned in the Introduction of this chapter, studies have shown evidence of broadened attention resulting from fearful faces (Taylor & Whalen, 2014). However, the impaired contextual learning by all faces in current results instead suggests that attention was narrowed, preventing learning of the global context. The discrepancy in findings may stem from the use of only fearful faces, without additional broader contextual information, in the current study. Thus, as a broadening of attention results from seeking to clarify the source of threat signalled by the fearful faces, the use of contexts solely containing fearful faces and a corresponding lack of broader contextual information may have obviated a search for potential sources of threat. Thus, instead, attention was focused on the individual faces.

3 Anxiety-Related Threat Effects on Memory-Based Orienting of Attention

Attention can be guided by expectations stemming from long-term memories. In addition to such endogenous cues, exogenous salient stimuli capture attention, such as those conveying threat. The two studies presented in this chapter examined the extent to which threatening distractors affect the employment of memories in guiding attention, and whether this is affected by trait anxiety. Fearful face distractors were incorporated into a speeded target detection task, in which memory cues were presented simultaneously with task-irrelevant emotional faces. In addition, the ISI was altered between the studies, with Experiment 1 using a long ISI range and Experiment 2 using a shortened ISI. The manipulation of ISI enabled the assessment of the duration of threat disruption, even in the absence of the threatening stimulus, thus reflecting the often transient nature of threat in the environment. At long ISIs, threatening distractors disrupted target detection, while neutral face distractors did not affect task performance. Moreover, such threat disruption was positively correlated with trait anxiety. Instead, when the ISI was reduced, both disruption by threat and the modulation by anxiety were eliminated. Taken together, the current findings reveal attentional capture by threat in the context of a second, powerful endogenous driver of attention that is contingent on sufficient time between the threatening stimulus and the memory cue. That is, threatening stimuli are sufficiently salient to induce prolonged disruption to goal-directed behaviour in anxious individuals.

3.1 Introduction

Experimental modelling of selective attention to threat allows for the careful characterisation of anxiety-related abnormalities in threat processing (Cisler & Koster, 2010; Yiend, 2010). Whilst cognitive paradigms such as the dot-probe task have played an important role in our understanding of the threat biases associated with anxiety, they have been criticised for a lack of sensitivity (Sigurjónsdóttir, Sigurardóttir, Björnsson, & Kristjánsson, 2015) and reliability (Grafton et al., 2017; Schmukle, 2005; Staugaard, 2009). Furthermore, the reliance on a limited set of methods to assess biased attention to threat may have hampered our understanding of the cognitive processes that are disrupted in anxiety. There remains a need to develop additional and

diverse methods to assess dysfunctional attention to threat in order to fine-tune theories, reveal mechanisms, and develop more effective cognitive treatments.

Existing paradigms typically examine the influence of threat on attention in isolation. For example, the dot-probe task presents competing stimuli of varying valence to assess their relative pull on attention. However, outside controlled laboratory settings, attention is not exclusively guided by threat but is driven by a myriad of competing biases. Our cognition is governed by current goals, and attention is consequently guided to optimise the fulfilment of these goals. Expectations about relevant upcoming events facilitate the perceptual analysis and selection of relevant stimuli by activating goal-related schemata in working memory and setting in motion anticipatory and preparatory functions (Desimone & Duncan, 1995; Gazzaley & Nobre, 2012; Theeuwes, Belopolsky, & Olivers, 2009). Furthermore, long-term memories provide an additional source of predictions that significantly enhances behavioural performance and neural processing of target stimuli occurring within learned, anticipated contexts (Chun & Jiang, 1999; Summerfield et al., 2006).

Exogenous threat distraction is likely to operate in the context of non-emotional endogenous cognitive biases that are deployed to support goal attainment. As threat has an exaggerated pull on attention in anxious individuals, it is plausible that the salience of threatening stimuli interferes with expectation-driven attention selection and that the magnitude of such interference correlates positively with trait anxiety. There are existing paradigms that examine threat biases in the context of emotion-related interference of the employment of expectations. For example, the Posner-style emotional spatial cueing paradigm presents neutral and threatening spatial cues that either validly or invalidly predict an upcoming target location (Fox, Russo, Bowles, & Dutton, 2001; Posner, 1980). Previous studies using this paradigm have demonstrated

threat biases in anxious individuals, indicated by quicker responding to valid threat-cued trials coupled with slowed responding to invalid threat-cued trials, compared to benign-cued trials (Bar-Haim et al., 2007; Cisler et al., 2009; Mogg, Holmes, Garner, & Bradley, 2008). Such tasks exploit external cues, which are internalised and are used to predict task-relevant events. However, most endogenous drivers of visual attention are intrinsic to a context, based on expectations built upon prior experience, stored within memories. For example, it has been established that long-term memories for target locations within previously encountered scenes can enhance perceptual sensitivity and response speeds to identify and discriminate targets in those scenes (Patai, Doallo, & Nobre, 2012; Summerfield, Gitelman, Mesulam, & Nobre, 2006). Considering the effect of threat on the processing of task-relevant endogenous signals in the Posner-style task, an appropriate follow-up inquiry is whether threatening stimuli may similarly affect the employment of learned intrinsic cognitive biases that are devoid of emotionality, and whether this is exacerbated in, or exclusive to, anxious individuals.

Therefore, the first aim of the following two studies was to investigate the effect of emotionally salient distractors on memory-guided attentional orienting, as well as the dependence of these effects on individual differences in trait anxiety. These studies complement investigations that have considered how emotional content intrinsic to material to be learned affects subsequent memory (e.g., Buratto, Pottage, Brown, Morrison, & Schaefer, 2014; Srinivasan & Gupta, 2010). My interest was in understanding whether distraction by emotional material interacted with everyday non-emotional, memory-based attentional biases, which are pervasive and highly adaptive in guiding performance (Chun & Turk-Browne, 2007). In order to investigate this, emotional distractors were incorporated into an existing memory-guided orienting task (Patai et al., 2012). In this task, participants explore visual scenes overtly to learn

the unique locations of hidden predefined targets (Figure 3-1a). Twenty-four hours later, participants perform a speeded target-detection task in which the previously learned scenes act as cues to orient attention based on participants' long-term memories of the target location in each scene. Using this paradigm, previous studies have reported significant benefits in the perceptual sensitivity and speed to identify and discriminate targets on valid, compared to invalid, trials (Salvato, Patai, & Nobre, 2016; Summerfield et al., 2006; Summerfield, Rao, Garside, & Nobre, 2011), demonstrating that participants' memories were effectively used to guide attention to learned target locations.

Both studies adapted this paradigm to include emotional distractors, which were presented simultaneously with the memory cues. A single fearful or neutral face was embedded in the cue scenes, and the extent to which the fearful distractors influenced subsequent target detection, as compared to neutral distractors, indexed emotion-related distraction. Thus, I was able to investigate the extent to which threat distractors captured attention in complex scenes so as to disrupt memory-based attention. I predicted that fearful faces would capture attention to a greater extent and consequently be more disruptive to task performance than neutral faces. Moreover, given that contemporary cognitive models of anxiety suggest that it is characterised by an over-dominance of exogenous, bottom-up drivers of attention, and impaired regulation of this by endogenous, top-down, goal-directed attentional control mechanisms (Eysenck, Derakshan, Santos, & Calvo, 2007), I predicted that the degree of distractor disruption would be positively associated with trait anxiety.

The second aim of the current studies was to examine the chronometry of threat biases. The sole methodological distinction between the studies was the duration of the ISI, with Study 1 using an ISI range of 750–1150 ms and Study 2 using a fixed 200-ms ISI. The manipulation of

ISI across the studies provided a direct comparison of the degree of threat distraction as a function of the lapse between distractors and targets. There is continued debate regarding the extent to which threat-related biases in anxiety are underpinned by an initial orienting to threat and/or by a subsequent difficulty in disengaging from threat. The temporal window of this distraction effect was investigated by Koster, Crombez, Van Damme, Verschuere, and De Houwer (2004), using a modified dot-probe paradigm (that included a condition of only neutral stimuli as a baseline comparison). Their results showed that anxiety-related attentional biases are marked by an impaired disengagement from threat, rather than an initial facilitation of threat detection. A study by Salemink, Hout, and Kindt (2007) similarly found that trait anxiety is linked to a disengagement difficulty from threat rather than facilitated orienting. However, other studies have yielded differing results. Using a visual search task, Byrne and Eysenck (1995) revealed facilitated detection of threatening faces in high trait anxious individuals relative to low anxious participants. Further, Koster, Crombez, Verschuere, Van Damme, and Wiersema (2006) used cue presentation times of 100 ms, 200 ms, and 500 ms in an exogenous cueing task and showed both greater facilitation and diminished disengagement at the 100-ms presentation time and subsequent attentional avoidance at 200-ms and 500-ms durations in high anxious participants. The discrepancy in findings across studies underscores the need for novel approaches to investigating the temporal dynamics of attentional biases to threat.

Studies examining attentional biases to threat often restrict their scope of investigation to responsivity to threat at early stages of processing (Schuyler et al., 2014). Indeed, threat processing paradigms typically present targets and emotional distractors either simultaneously, as is done in visual search or emotional Stroop paradigms, or within roughly 500 ms of one another, as in dot-probe paradigms (Most, Chun, Widders, & Zald, 2005; Vuilleumier, Armony, Driver, &

Dolan, 2016). However, an alternative approach is to systematically vary the time between stimuli, rather than the temporal features of the stimuli themselves. As real stimuli in the environment are dynamic and thus oftentimes transient, presenting stimuli briefly allows for a more realistic depiction of everyday perceptual and attentional processing. Manipulation of the ISI enables an assessment of the persistence of attentional biases in the absence of threatening stimuli. Short ISIs would reflect an early rapid attention to a stimulus, while long ISIs would provide an index of extended engagement with the stimuli, even once they are no longer present. Forster, Nunez-Elizalde, Castle, and Bishop (2014) adopted this approach to examine the time window of distraction effects in anxious individuals. The authors found that the degree of task disruption caused by a threatening distractor was modulated by trait anxiety at ISIs of ~3 seconds but not at ISIs of ~1.6 seconds. The shorter ISI was posited to fall within the 'responsivity' period while longer ISIs reflect a subsequent 'recovery' phase; these time windows were taken from findings regarding amygdala responses to negative stimuli (Schuyler et al., 2014). The authors concluded that anxiety is characterised by an inability to recover from aversive stimuli, rather than an initial response to these stimuli. These findings elucidate the important role of ISI durations in eliciting different attentional profiles in anxious individuals. Thus, to chart the temporal aspects of threat distraction, the current set of studies was conducted using long and short ISIs. However, the ISIs used were relatively shorter to those used in previous studies in order to best mimic the memory-guided orienting tasks previously used (Patai et al., 2012; Summerfield et al., 2006, 2011).

Comparable findings of an anxiety-related threat distraction across these studies would suggest that attentional biases in anxious individuals are marked by both early reactivity (short ISI) and impaired recovery (long ISI). Different patterns of effects by threat-related attention at

different intervals relative to memory-related attention would provide important information about the temporal nature of biases, suggesting that they are marked by a specific time course.

3.2 Experiment 1[12]

3.2.1 Methods

Participants

Thirty-two participants, aged 19–26 years (mean age = 20.9 years, *SD* = 1.78; 22 females), were recruited through an online participant database and through online adverts and local flyers. The current sample size is comparable to other studies investigating anxiety-related threat biases (Fox, 2008; Koster et al., 2006). All participants had normal or corrected vision, had no history of neurological or psychiatric illness, and were fluent in English. Participants gave their written informed consent and were compensated £10/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC-C1-2014-075).

Procedure

Participants attended two test sessions at the Department of Psychiatry at the University of Oxford, conducted 24 hours apart. In the first session, participants completed paper versions of the trait anxiety scales of the Spielberger State-Trait Anxiety Inventory (STAI-T; Spielberger,

[12] This study was accepted for publication: Raeder, S. M., Bone, J. K., Patai, E. Z., Holmes, E. A., Nobre, A. C., & Murphy, S. E. (2019). Emotional distraction in the context of memory-based orienting of attention. *Emotion*.

1983), the Beck Depression Inventory (BDI-II; Beck et al., 1996) and the Neuroticism subscale of the Eysenck Personality Questionnaire (EPQ-N; Eysenck & Eysenck, 1975). Results of questionnaires are shown in Table 3-1. They then completed the Learning task. The following day, participants returned to complete the Orienting and Memory tasks, which were always completed in this order.

STAI-trait	39.19 (± 1.09)	28–50
BDI-II	4.25 (± 0.70)	0–19
EPQN	2.96 (± 0.34)	0–7

Table 3-1: Questionnaire results. Means are shown with *SEM* in parentheses and range on the far right.

Stimuli

Scenes and Keys

One hundred and sixty-eight everyday scenes (see Figure 3-1A for examples) were taken from an existing database obtained collectively by the laboratory. The set consisted of 35 indoor scenes and 133 outdoor scenes with varied content. The presence of people was kept at a minimum, as was the use of large, salient objects in the foreground. Given their intended naturalistic quality, there was inevitable variability across scenes. However, by counterbalancing the scenes across experimental conditions, I was able to ensure that intrinsic characteristics of the scenes did not

affect results. Scenes were sized 1000 × 750 pixels and subtended 22° × 17° of the visual angle when viewed from a distance of 100 cm. In the Learning task, a gold key (15 × 29 pixels, equivalent to 0.3° × 0.7°) was embedded in one of the four quadrants of the scene. In the Orienting task, the key was larger and brighter (25 × 49 pixels, equivalent to 0.6° × 1.1°) to enhance contrast and thus prevent chance-level accuracy rates.

Faces

A total of 168 coloured face stimuli were used in the Orienting task. The face stimuli were taken, with permission, from the Amsterdam Dynamic Facial Expressions Set (van der Schalk et al., 2011), Pictures of Facial Affect (Ekman & Friesen, 1976), the Radboud Faces Database (Langner et al., 2010), and the MacArthur Network Face Stimuli Set (Tottenham et al., 2009). A total of 84 different face identities were used (50 male), each with a fearful and a neutral expression (see Figure 3-2A for example). A standardised oval was used to crop the faces to ensure that the faces were of equal size across trials. The oval was placed so as to include only the eyes, nose and mouth, part of the chin, and the top of the hairline. Faces were 91 × 140 pixels (equivalent to 2.1° × 3.2° when viewed from 100 cm). An additional face, taken from the Facial Expressions and Emotion Database of the Technical University Munich (Wallhoff, 2005), was used for the practice trials of the Orienting task. This face was pixelated using Adobe Photoshop (version CS6), creating a 91 × 140-pixel oval.

Tasks

The entire memory-guided orienting experiment consisted of three experimental phases: a Learning task; an Orienting task; and a Memory task.

Learning Task

The Learning task was based on that reported by Patai et al. (2012). Participants were instructed to search for a small gold-coloured key (target) in each of 168 scenes. Scenes were viewed one at a time, and participants searched for the key embedded in one of the four quadrants (Figure 3-1A). They were free to move their eyes (overt search). Once they had located the key, participants responded by clicking the mouse to activate the cursor and then positioning it on the key location. Following the response, visual written feedback (1000 ms) was provided (i.e. '*key found'* or '*key not found'*) on each trial. Scenes remained on the screen for two minutes or until a response was made. If participants did not respond within two minutes, they received feedback reading '*key not found',* followed by the start of the next trial.

After searching for the key in all 168 scenes, participants took a brief break and then repeated the procedure for the same set of scenes. In total, participants completed the procedure five times. The key remained in the same location within each scene for each of these five learning blocks, thereby allowing participants to form spatial-contextual memories of the location of the key in each scene. The presentation order of scenes was randomised in each block. Written feedback was presented at the conclusion of each block, indicating the total fraction of keys found. Search times and accuracy were recorded. A circle with a radius of 50 pixels around the target (key) defined the region within which responses were deemed accurate. Scenes for which participants did not locate the key in two or more blocks were excluded from further analyses. One participant did not successfully locate the key in one of the scenes in two of the blocks and this participant's data for this scene was excluded from further analyses.

Orienting Task

The Orienting task was performed 24 hours after the Learning task (Figure 3-2A). Participants were instructed to maintain central fixation during each trial by continually fixating on a central cross, which remained on the screen throughout the entire task. Participants were asked to try to refrain from blinking during scene presentations.

Participants first completed a practice session containing 12 novel scenes with a distracting scrambled face. Using a scrambled face during the practice session allowed participants to become accustomed to the appearance of distractor stimuli without habituating to face valence. Participants were first shown a novel cue scene for 100 ms, featuring the scrambled face. After an ISI ranging from 750 to 1150 ms, the same scene reappeared for 200 ms; the key was present in half of these target scenes in a randomly varied location. Participants had to indicate whether the key was present or absent by making a forced-choice response using the mouse. After completing the practice session, participants were given the opportunity to clarify any outstanding questions and then started the task.

In the experimental task, each trial began with the brief presentation of a cue scene, which was a scene that participants had previously been exposed to during the Learning task. This cue scene was presented for 100 ms and had a fearful or neutral face embedded in it. The key was never present in the cue scene. After a random ISI ranging from 750 to 1150 ms, the same scene was presented again without the face for 200 ms. On half of the trials (i.e. on 84 trials), this scene contained the target key, which was located in either a valid (learned) or in an invalid (novel) location in the opposite hemifield. Trials in which the key was present were equally divided into valid and invalid trials (42 trials each). On the remaining 84 trials, the key was not present in the scene. Participants were asked to indicate whether the key was present or absent via a left or right

mouse click, respectively, and were given a 1000-ms time window to respond. After a random ITI of 750 to 1150 ms, the next trial began. Self-timed breaks were provided after every 14 trials. During the cue scene, faces were always located in a different quadrant from both the learned (valid) and novel (invalid) key location. That is, faces never cued valid or invalid key locations and were therefore always distractors. Participants were told that the faces were not relevant to the task and were instructed to ignore them.

All 168 scenes from the Learning task were included in the Orienting task and the assignment of each scene according to the experimental conditions of target presence (present, absent), validity (valid, invalid), and face emotion (fearful, neutral) was counterbalanced across participants, resulting in eight versions of the task. Accuracy of target detection and RTs were used as outcome measures on this task. Individual raw RTs above or below three standard deviations across conditions were excluded from the analyses for each participant. This resulted in the mean removal of 2.6% of trials. Trials removed from RT analyses on this basis were also excluded from the accuracy analyses.

Memory Task

Following the Orienting task, participants completed a memory recall test. In this task, participants viewed each of the 168 scenes in turn, and indicated the learned location of the key (Figure 3-3A). After indicating the remembered location by positioning the cursor on the location and using a mouse click to place their response, participants were asked to complete a confidence rating of their memory (‘not at all’, ‘fairly’, ‘very’ confident), using the left, centre, and right mouse buttons, respectively. Feedback was not provided for memory recall. Mean distance between the original and indicated key locations was used as an index of spatial recall; this was

calculated as the Euclidean distance between the *x*- and *y*-coordinates of response and actual key locations.

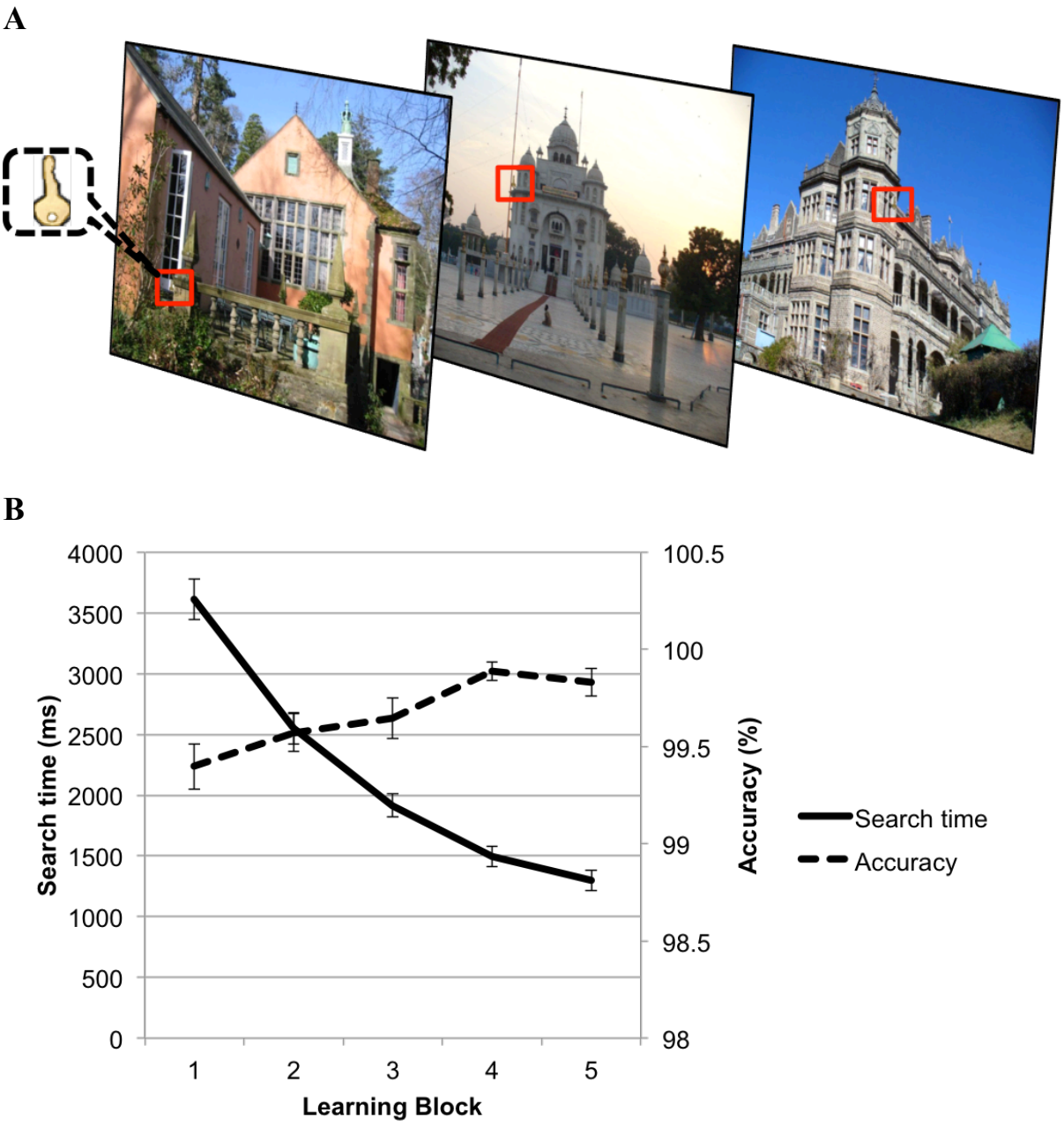
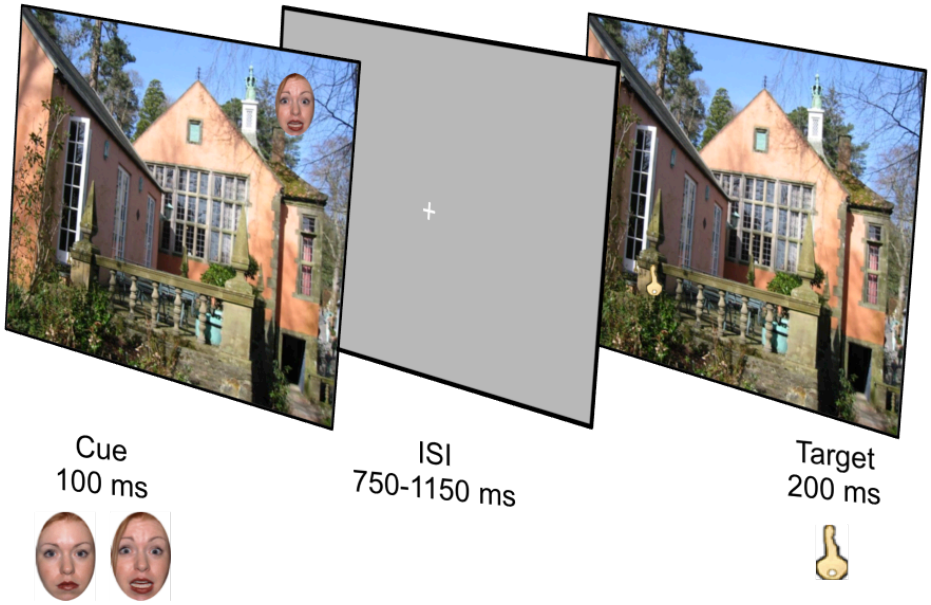
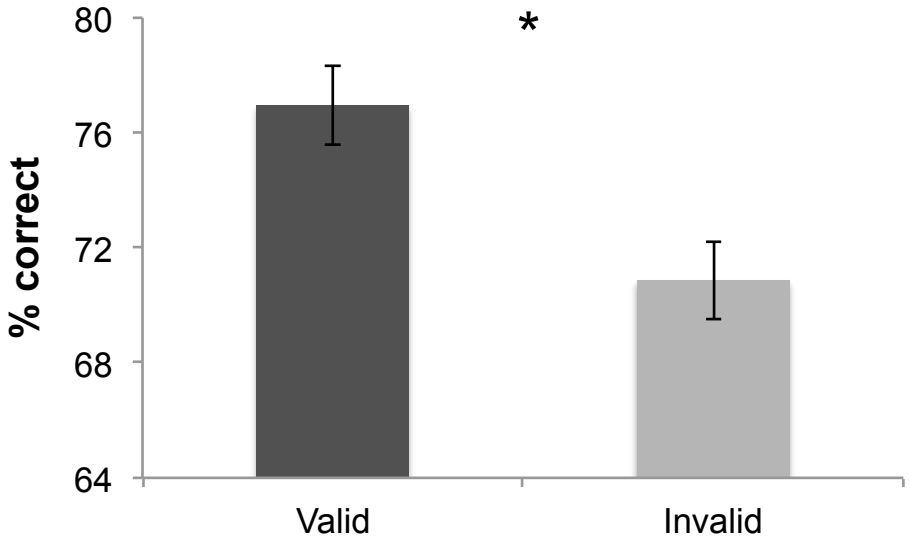


Figure 3-1: Learning task: design and results. (A) Participants overtly searched for keys, located in 1 of 4 quadrants, for 168 naturalistic scenes (three examples shown, red box, indicating key location, is included for illustrative purposes only). (B) Over the course of learning blocks, participants became more accurate and quicker at detecting targets.

A


Cue
100 ms
ISI
750-1150 ms
Target
200 ms

B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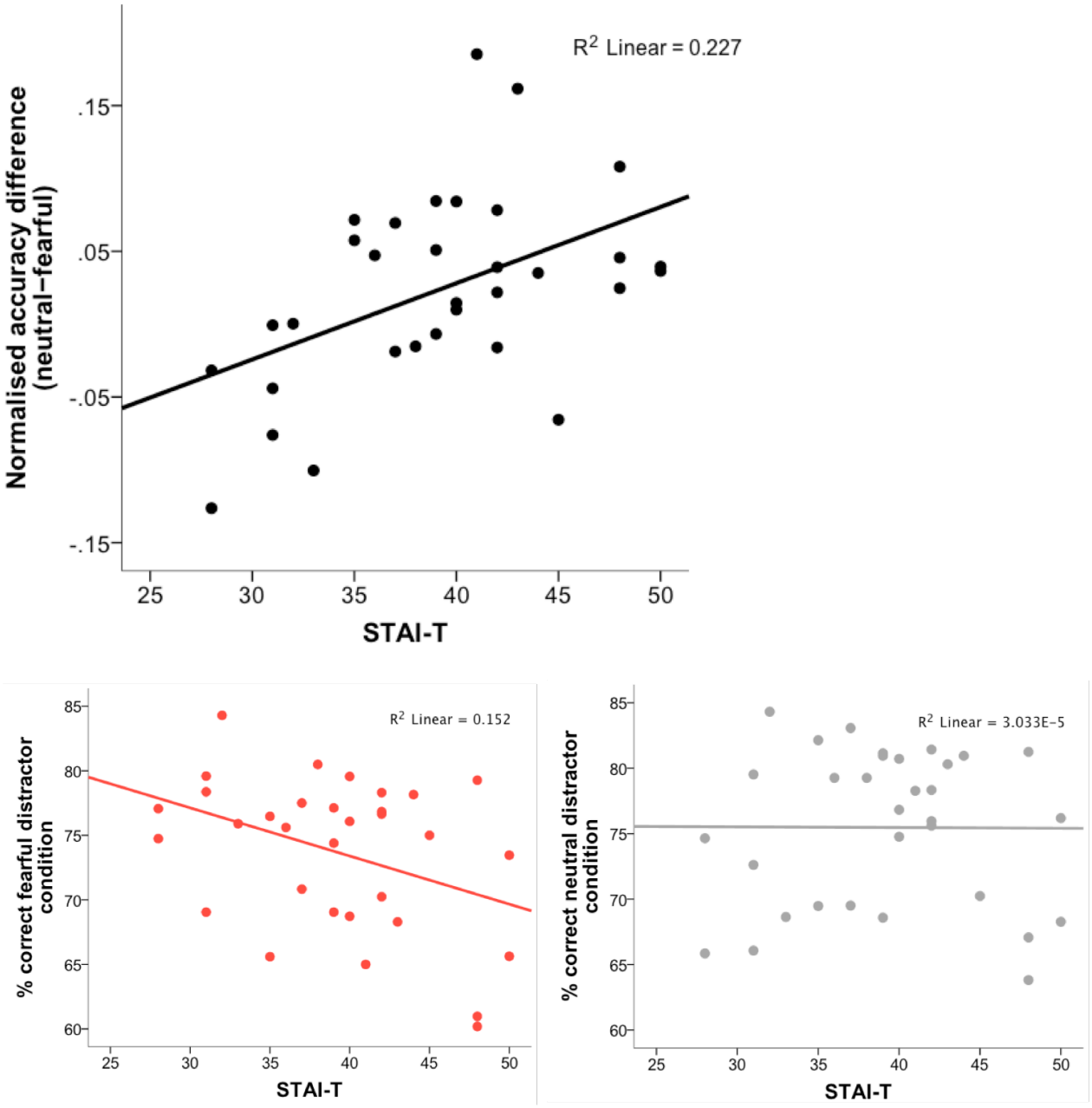


Figure 3-2: Orienting task: design and results. (A) Cue scenes containing either fearful or neutral faces were presented for 100 ms. After an ISI ranging from 750–1150 ms, target scenes, which presented the key on half the trials, appeared for 200 ms. (B) All participants showed a significant validity effect for accuracy indices, whereby they exhibited greater accuracy for valid versus invalid trials. Error bars represent ± 1 *SEM*. Asterisk indicates significant differences between valid and invalid conditions ($p \leq .05$). (C) There was a significant positive correlation between STAI-T scores (*x*-axis) and difference in mean accuracy between neutral and fearful face distractor conditions (*y*-axis) (top). Separate correlations for each emotion condition confirmed that STAI-T was significantly negatively correlated with accuracy on trials containing fearful face distractors (bottom left), while STAI-T did not correlate with accuracy on trials with neutral face distractors (bottom right).

Figure 3-3: Memory task: design and results (A) Participants indicated the learned location of the key, followed by a confidence rating. (B) Mean distance (*y*-axis) from target location as a function of confidence ratings (*x*-axis). Mean distance decreased as confidence ratings increased. Error bars represent ± 1 *SEM*.

3.2.2 Analysis

The data were analysed using ANCOVA, with task conditions included as within-subjects factors and trait anxiety (STAI-T) scores included as a continuous predictor.

Across analyses, where the assumption of sphericity was violated, degrees of freedom were adjusted using either Greenhouse-Geisser or Huynh-Feldt corrections; if $\varepsilon > 0.75$, a Huynh-Feldt correction was applied (Field, 2011; Girden, 1992). All post-hoc tests were conducted with Bonferroni correction.

3.2.3 Results

Participants' trait anxiety scores ranged from 28 to 50, inclusive (M = 39.2, SD = 6.2, Figure 3-4). These scores are similar to the published norms for this age group (M = 36, SD = 10) (Spielberger, 1983). The Shapiro-Wilk test (Shapiro & Wilk, 1965) revealed that the distribution of STAI-T scores did not significantly deviate from normal (p = .44).

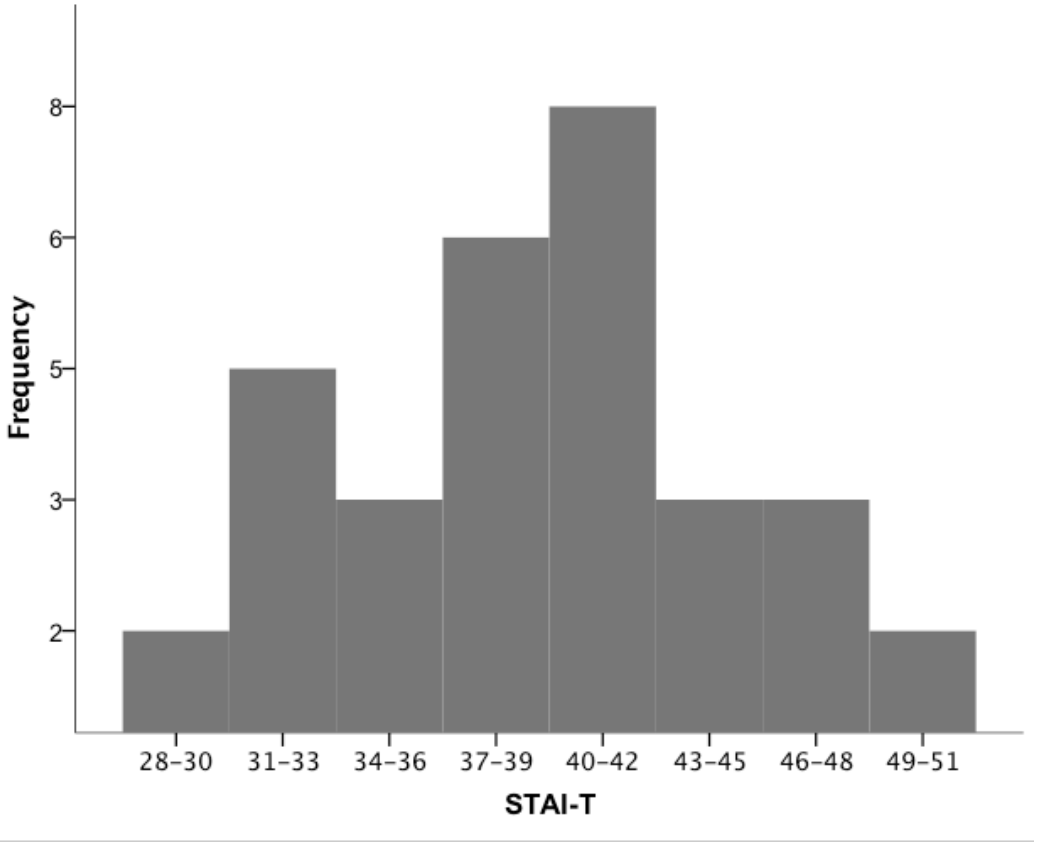


Figure 3-4: The spread of STAI-trait scores.

Learning Task

Search times decreased and accuracy increased with learning over the five overt-search blocks (Figure 3-1B). Because of the long time allowed for searching for the target within each scene, the accuracy for locating the target key was consistently high from the first learning block (accuracy, *SD*, range: 99, 0.70, 1.80 %). Nevertheless, ANOVAs testing for linear increases in accuracy showed a main effect of learning block [F (3.24, 97.13) = 5.62, p = .001, η_p^2 = .16][13] and

[13] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 23.04, p = .006. Huynh-Feldt correction was applied (ε = .83). Corrections were applied to interactions with trait anxiety.

a significant linear contrast over the learning blocks [F (1, 30) = 17.76, p < .001, η_p^2 = .37]. Reaction times showed strong modulation over learning. There was a significant main effect of learning block [F (1.55, 48.10) = 159.59, p < .001, η_p^2 = .84][14] and a significant linear decrease in search times over blocks [F (1, 31) = 217.19, p < .001, η_p^2 = .88].

To assess potential anxiety effects, a mixed-model ANCOVA was conducted with a within-subjects factor of block (1–5) and with trait anxiety (STAI-T) as a continuous predictor. There was no main effect of trait anxiety or interaction between trait anxiety and block for accuracy [main effect: F (1, 30) = 0.49, p = .49; interaction: F (3.36, 100.92) = 0.56, p = .66][15] or search times [main effect: [F (1, 30) = 1.30, p = .26; interaction: F (1.56, 46.83) = 1.12, p = .33][16]. Anxiety therefore did not impact the formation of new spatial-contextual associations for non-emotional targets within scenes. The comparable learning across trait anxiety provides a clean baseline for the subsequent Orienting task, allowing for anxiety-related emotional capture effects to clearly be isolated.

Orienting Task

A mixed-model ANCOVA was conducted on accuracy (percent correct) scores using within-subjects factors of validity (valid, invalid) and face emotion (fearful, neutral) and trait anxiety as a continuous predictor. This showed a significant main effect of validity [F (1, 30) = 4.03, p = .054, η_p^2 = .12], reflecting a modest (6%) increase in accuracy on valid compared to invalid trials

[14] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 13.68, p < .001. Greenhouse-Geisser correction was applied (ε = 0.39). Corrections were applied to interactions with trait anxiety.

[15] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 23.60, p = .005. Huynh-Feldt correction was applied (ε = 0.84).

[16] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 132.01, p < .001. Greenhouse-Geisser correction was applied (ε = 0.39).

[valid: 77.6%, 95% confidence interval, CI = (75.4%, 79.8%) invalid: 71.6%, CI = (69.2%, 73.9%)] (Figure 3-2B). There was also a significant main effect of emotion [F (1, 30) = 6.10, p = .019, η_p^2 = .17], reflecting an increase, albeit small (< 2%), in accuracy on trials preceded by a neutral face compared with a fearful face [mean percent correct: neutral 75.5%, CI = (73.3, 77.7), fearful 73.7%, CI = (71.7, 75.7)], and a significant interaction between face emotion and trait anxiety [F (1, 30) = 8.13, p = .008, η_p^2 = .21]. To clarify this face emotion × trait anxiety interaction further, the difference in mean accuracy for fearful versus neutral conditions, normalised against the overall mean accuracy across conditions, was used to test for correlations between emotional distraction and STAI-T scores. This yielded a significant positive correlation [r = .48, p = .006]. Separate correlations between STAI-T and accuracy on trials containing fearful face distractors and accuracy on trials with neutral face distractors revealed that anxiety was significantly negatively correlated with accuracy on fearful face distractor trials [r = -.39, p = .027], while the correlation between anxiety and accuracy on neutral face distractors trials was not significant [r = -.006, p = .98] (Figure 3-2C).

As both neuroticism and depression are often comorbid with anxiety, separate analyses were conducted using neuroticism (EPQN) and depression (BDI) scores to assess whether the observed threat distraction was additionally driven by neuroticism and depression.

The Shapiro-Wilk test revealed that EPQN scores were normally distributed (p = .14). However, BDI scores showed a non-normal, positive skewed distribution (p < .001). Thus, a log transformation was conducted on BDI scores, which resulted in a normal distribution (p = .18). Two ANCOVAs were conducted on accuracy, with the respective continuous predictors of neuroticism and depression, and validity and face emotion as within-subjects factors. The analysis using neuroticism scores revealed a significant validity effect [F (1, 30) = 11.30, p =

.002, η_p^2 = .27]. There were no further main effects or interactions (all p's > .091). The ANCOVA using depression scores showed a significant main effect of validity [F (1,30) = 10.46, p = .003, η_p^2 = .26]. There were no further main effects or interactions (all p's > .20).

Reaction times were not of primary interest in this task, which required a forced-choice response based on a difficult perceptual discrimination. Nevertheless, RTs were analysed for completeness. Reaction times were compared for correct trials. Analysis of RTs revealed no significant main effects or interactions (all p's > .33).

Finally, as participants indicated the absence or presence of target keys using left and right mouse clicks, respectively, potential spatial compatibility effects were assessed, i.e. whether participants were more accurate and quicker in indicating 'key present' when keys were located on the left hemifield. Accuracy and RTs were computed for trials in which the key was presented on the left versus right hemifield (a spatially compatible versus incompatible stimulus-response). Paired samples t-tests showed no differences in both accuracy and RTs for compatible versus incompatible trials (all p's > .42).

Memory Task

The mean distance between the original and indicated key locations was 207.56 pixels (*SD* = 79.47). Participants' confidence ratings varied in accordance with the mean distance between their response and the actual key location; as they became less confident, their accuracy decreased (Figure 3-3B).

To determine whether target validity and distractor emotion from the preceding Orienting task affected subsequent recall, as indexed by mean distance, a mixed-model ANCOVA was conducted with within-subjects factors of validity (valid, invalid) and face emotion (fearful,

neutral), and trait anxiety (STAI-T) as a continuous predictor. There were no significant effects of validity, emotion, or trait anxiety, and no significant interactions (all p's > .39). The lack of interaction between emotion and anxiety suggests that recall for fearful versus neutral faces did not differ as a function of anxiety.

Paired samples *t* tests confirmed that there was no significant difference in recall between trials in which the key was absent and trials in which they key was present in the Orienting task [$t(31) = 1.29$, $p = .21$].

Finally, to determine whether the location of the previous distractor faces influenced participants' explicit memories of the target locations, I compared the incidence of participants incorrectly indicating that the memorised target location was in the quadrant previously occupied by the distractor face versus in either of the other two incorrect quadrants. A comparison of these quantities revealed no significant differences in the quantity of errors occurring in the quadrant of the face and the average quantity of errors occurring in the remaining two quadrants [$t(31) = 0.88$, $p = .34$]. Further, STAI-T did not significantly correlate with these quantities (all p's > .18). These results suggest that the previous locations of the distractor faces did not affect participants' explicit memories.

3.2.4 Interim Discussion

Consistent with my predictions, results from Experiment 1 showed that fearful face distractors disrupted performance on a subsequent target detection task significantly more than neutral face distractors. Importantly, the extent to which fearful faces were more disruptive to task performance was positively correlated with trait anxiety scores.

The precise mechanisms underlying threat-related attentional biases remain unclear, with particular disagreement as to whether they are driven by a heightened initial vigilance towards threat and/or a subsequent impairment in disengaging from such threat. Clarifying the underlying mechanisms has often been addressed by varying stimuli presentation durations. However, a potentially more informative approach is to vary the timing between threat and task-relevant information. As threat is often transient in our environment, it is crucial to understand the potential prolonged effects of threat on subsequent processing, even in its absence.

Experiment 2 was designed in order to make further inroads in determining whether anxiety is characterised by early responsivity to threat or subsequent difficulties in disengaging from threat. Rather than manipulating stimulus duration, the interval between the irrelevant, threat-related stimulus and the task-relevant target stimulus was curtailed to 200 ms. Taken together, results from both experiments will provide key insight into modulations of threat distraction as a function of ISI.

Three additional modifications were made in Experiment 2. First, an explicit face recall task was administered as a means of gauging the degree of participants' awareness of distractor emotion. Second, the state scale of the Spielberger State-Trait Anxiety Inventory was administered in order to assess whether threat distraction is driven by state anxiety, i.e. transient and situation-induced anxiety. Finally, a dot-probe task using valenced word stimuli was administered subsequent to the memory-guided orienting task. Administration of this task enables a direct comparison of threat biases measured by an established paradigm with biases measured by the current novel paradigm.

3.3 Experiment 2

3.3.1 Methods

Participants

Forty-eight participants, aged 19–32 years (mean age = 23.5, *SD* = 3.57; 30 females), were recruited through an online participant database, local adverts, and Facebook adverts. Upon signing up for the study, participants were asked to answer a set of pre-screening questions and to complete the STAI-trait questionnaire via Qualtrics (Qualtrics, Provo, UT). The purpose of pre-screening was not only to ensure inclusion criteria were met, but also to obtain a spread of anxiety scores comparable to those in Experiment 1.

Exclusion criteria were identical to those in Experiment 1. Participants gave their written informed consent and were compensated £10/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC-C1-2014-075).

Procedure

Participants attended two test sessions at the Department of Psychiatry at the University of Oxford, which were conducted 24 hours apart. In the first session, participants filled out both the trait and state scale of the STAI-T, the STAI-state, the BDI-II, and the EPQ-N. The pre-screening STAI-T scores were used to ensure an adequate spread of scores and comparable scores to Study 1; however, the scores obtained on the actual testing day were used to allocate participants to respective groups. Questionnaires were completed on Qualtrics. Results of questionnaires are shown on Table 3-2. Participants then completed the Learning task of the memory-guided

orienting paradigm, which was identical to that used in Experiment 1. This first session took approximately 2 hours. The following day, participants returned to complete the Orienting task, with an altered ISI of 200 ms, and the Memory task, with the additional face recall test. At the conclusion of the Memory task, participants performed the dot-probe task. The second session took approximately 1.5 hours.

STAI-trait	38.79 (± 1.49)	22–62
STAI-state	33.00 (± 1.40)	20–60
BDI-II	6.44 (± 1.0)	0–28
EPQN	3.60 (± 0.49)	0–11

Table 3-2: Questionnaire results. Means are shown with *SEM* in parentheses and range on the far right.

Task

The Learning task was identical to that used in Experiment 1. The Orienting task was modified so that the ISI was fixed at 200 ms (Figure 3-6A). The Memory task for the key location was kept the same as the previous study. However, a face recall task was added in which participants were shown a pair of neutral and fearful faces, of the same actor, and were asked to indicate which of the two faces was present in the scene in the preceding Orienting task (using the left/right mouse button). Faces were presented after each scene, against a black background. The purpose of this forced-choice task was to monitor the extent to which participants were consciously aware of the

faces during the previous Orienting task. After selecting one of the two faces, participants completed a confidence rating ('not at all', 'fairly', 'very' confident), using the left, centre, and right mouse buttons, respectively (Figure 3-7A). As in Experiment 1, there were eight versions of the task.

The dot-probe task included 96 pairs of words, with each pair containing one threatening word (e.g. *stress*) and one benign word (e.g. *cities*) of equal length. Words were taken from the study by MacLeod et al. (2002). Words, rather than faces, were chosen as stimuli so as to prevent carryover effects from the valenced faces used in the preceding memory-based orienting paradigm. The original form of the dot-probe task requires participants to simply detect the position of a probe on a display (MacLeod et al., 1986). This response requirement, however, cannot control for the adoption of a strategic selective spatial monitoring. That is, participants may adopt the strategy to attend solely to one stimulus location, as this suffices for correct responding. A remedy for this limitation is to use a probe-classification task, which requires participants to respond to certain features of the probe and therefore to attend equally to both locations on the display. Thus, a classification task was used in the current study. Word pairs were presented for 500 ms, after which one of the two words was replaced by either one or two dots, which remained on the screen until participants responded. Participants were asked to indicate as quickly as possible whether a single or double dot was displayed, using the corresponding number keys (#1, #2). After participants responded, the following trial began after 500 ms. The position of the threatening word was randomised, such that it appeared in the top or bottom location with equal probability on any trial. Threatening and neutral words were both replaced by single dots on half of the trials and by double dots on the remaining half.

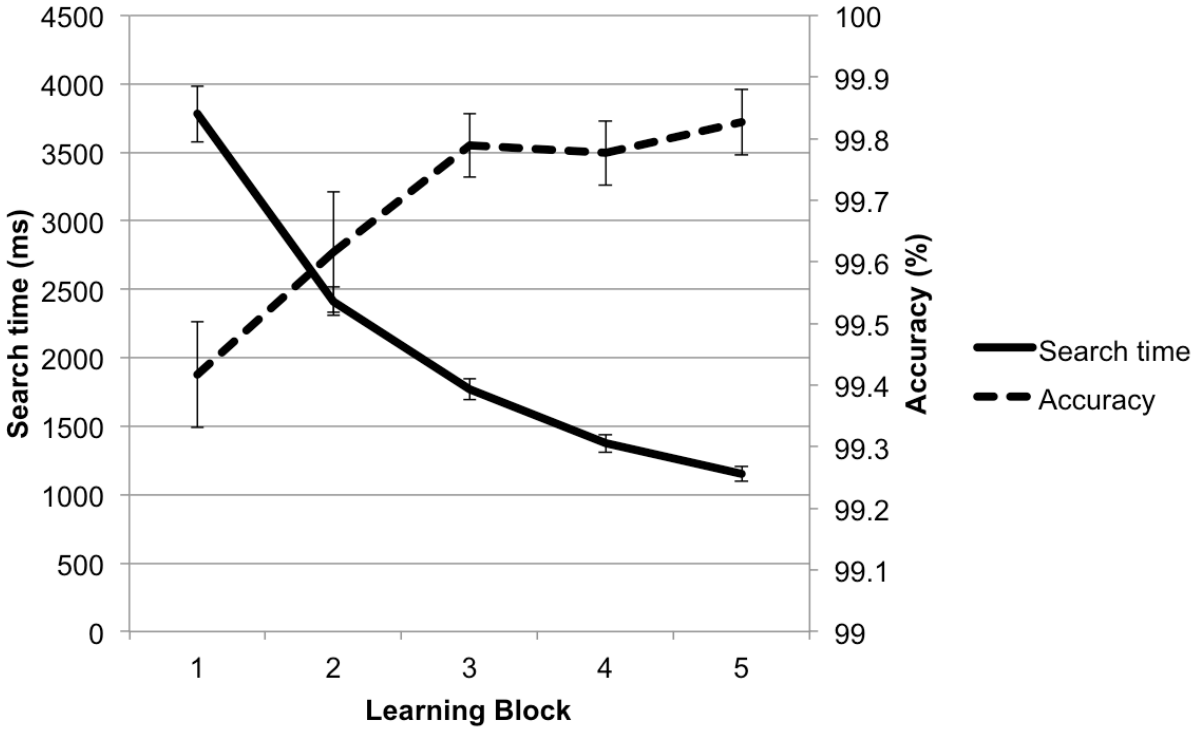
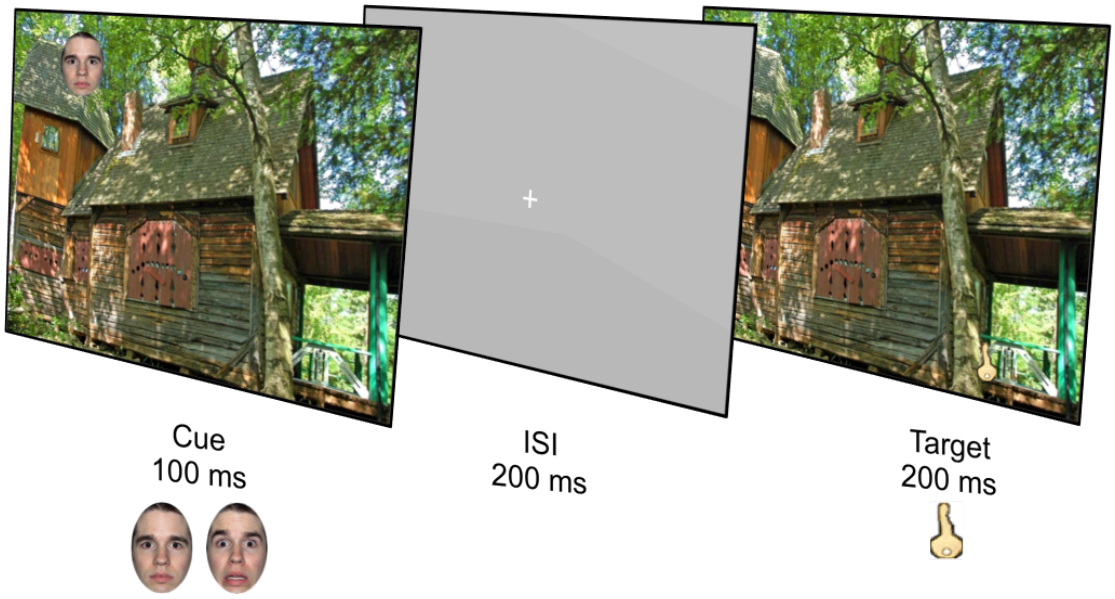


Figure 3-5: Learning task results: Participants demonstrated improved accuracy and decreased search times over the course of the five learning blocks.

A



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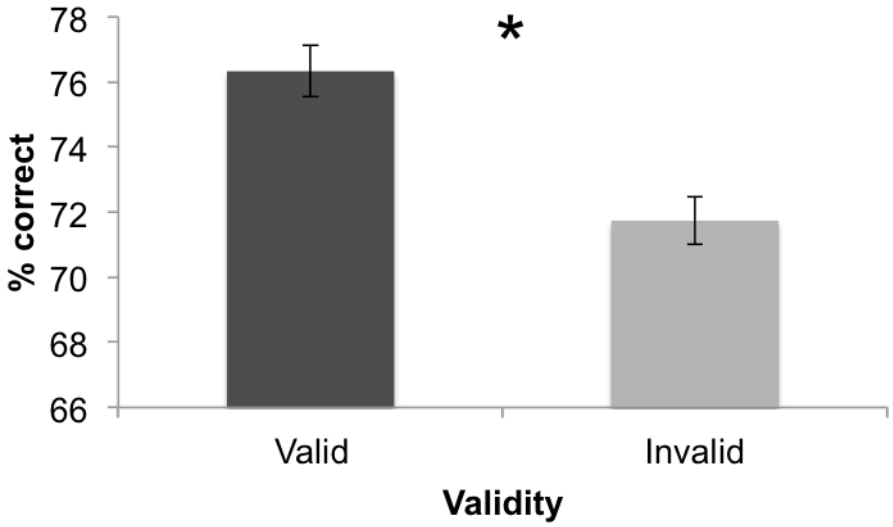
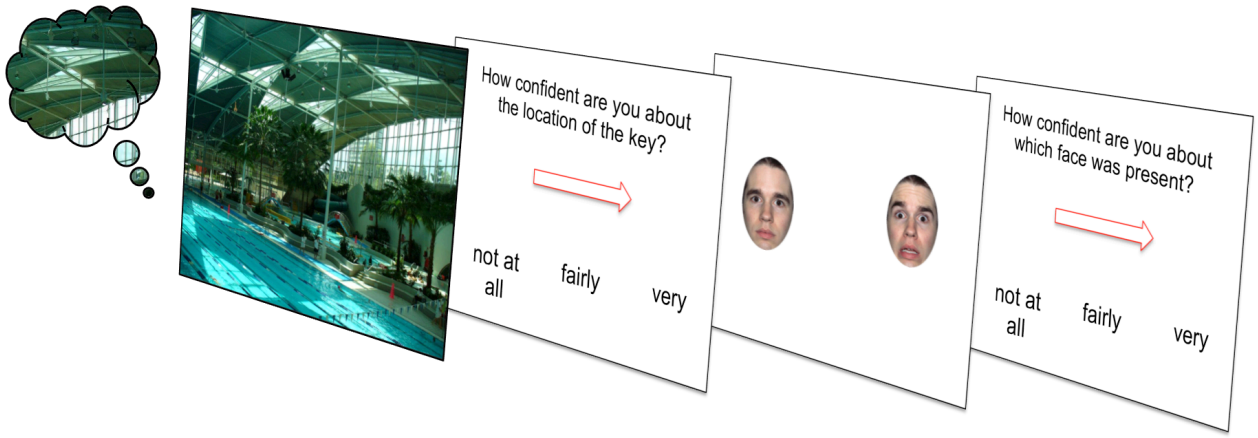


Figure 3-6: Orienting task: design and results (A) The ISI was shortened to 200 ms. All other features were kept identical to Experiment 1. (B) All participants showed a significant validity effect, with greater accuracy for valid versus invalid trials. Asterisk indicates significant differences between valid and invalid conditions ($p \leq .05$).

A



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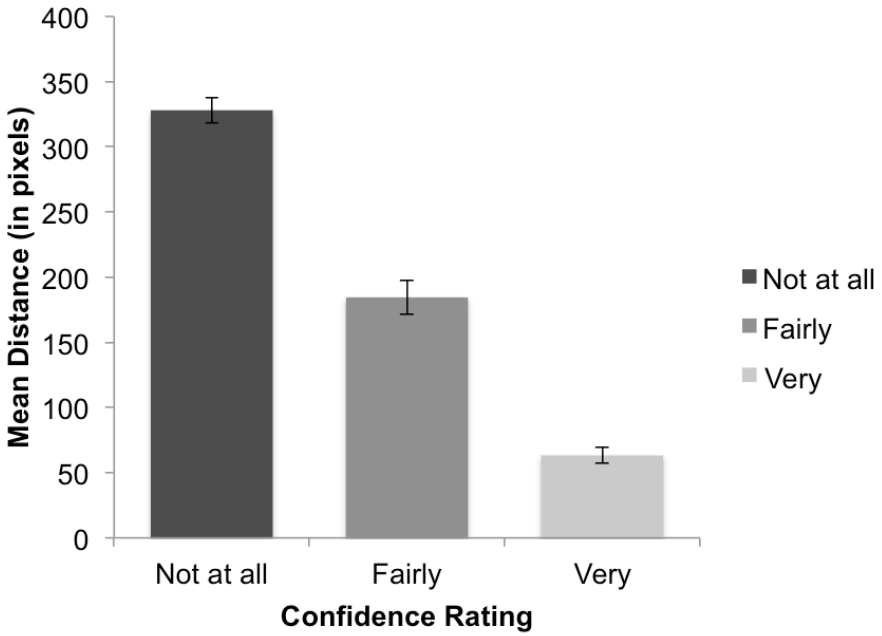


Figure 3-7: Memory task: design and results (A) Participants indicated the learned location of the key, followed by a confidence rating, and subsequently selected which face was presented in that scene in the preceding Orienting task. Each pair included a neutral and fearful face of the same actor. (B) Mean distance (*y*-axis) from target location as a function of confidence ratings (*x*-axis). Mean distance decreased as confidence ratings increased. Error bars represent ± 1 *SEM*.

3.3.2 Analysis

Analyses for the Learning, Orienting, and Memory tasks were identical to Experiment 1. Removal of individual raw RTs in the Orienting task resulted in the exclusion of 2.3% of trials.

As in Experiment 1, where the assumption of sphericity was violated, degrees of freedom were corrected using either Greenhouse-Geisser or Huynh-Feldt estimates of sphericity, depending on the ε value. All post-hoc tests were conducted with Bonferroni correction. An alpha level of .05 was selected as the minimum point for rejection of null hypotheses.

For the dot-probe task, trials with errors were removed for each participant (mean of 2% across participants). For the remaining accurate trials, RTs below 200 ms or exceeding 3 standard deviations of individual means were excluded (mean of 1.5% across participants).

3.3.3 Results

Scores on the STAI-T ranged from 22–62, inclusive (M = 39.79, SD = 10.30) (Figure 3-8). These scores were similar to those in Experiment 1[17]. The Shapiro-Wilk test (Shapiro & Wilk, 1965) revealed that the distribution of STAI-T scores was normal (p = .30).

[17] An independent t test showed no significant difference in STAI-T scores between the two experiments [t (77.22) = -0.33, p = .74]. Levene's test indicated unequal variances (F = 11.04, p = .001), so degrees of freedom were adjusted from 78 to 77.22.

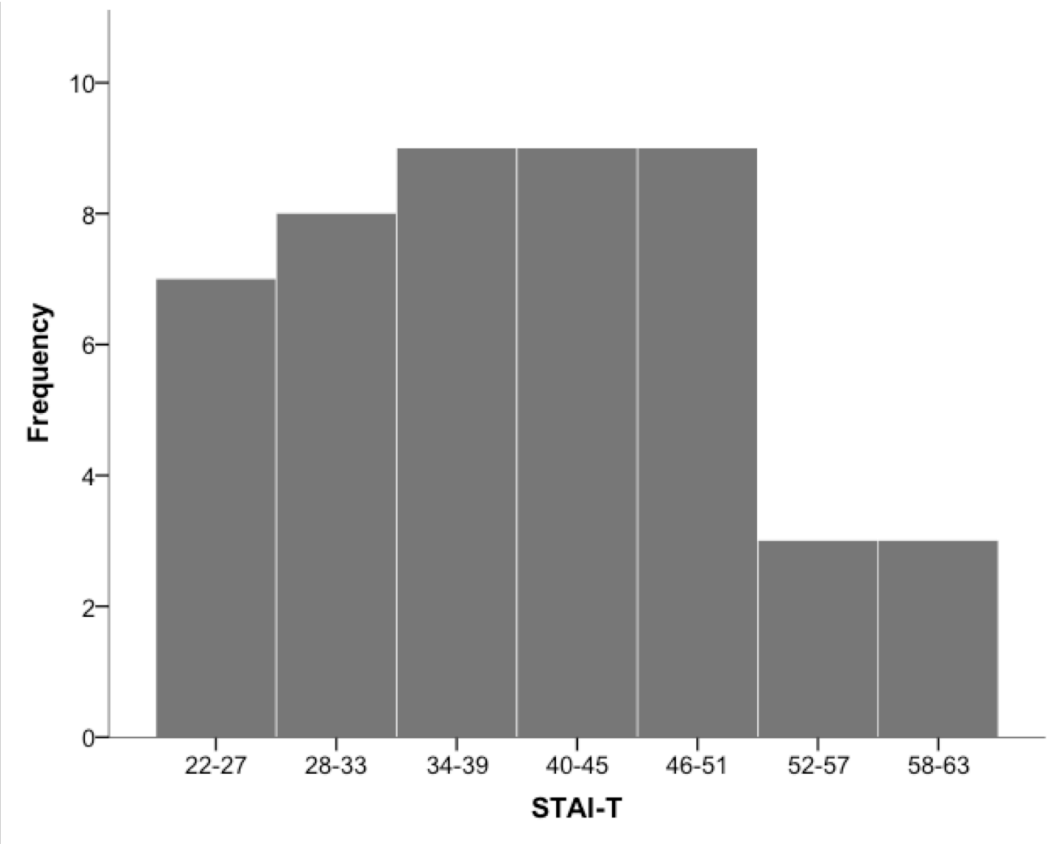


Figure 3-8: The spread of STAI-trait scores.

Learning Task

As in Experiment 1, a circle with a radius of 50 pixels around the key defined the region within which responses were deemed accurate. Scenes for which participants did not locate the key in two or more blocks were excluded from further analyses. Two participants did not successfully locate the key in one of the scenes and therefore data for these scenes were excluded from the participants' data.

There was an overall decrease in search times and an increase in accuracy across the five learning blocks, indicating that participants successfully learned the location of the keys in the scenes (Figure 3-5). Similar to results from Experiment 1, the accuracy for locating the target key was consistently high from the first learning block (accuracy, *SD*, range: 99.4, 0.006, 0.024 %). ANOVAs testing for linear increases in accuracy showed a significant main effect of learning block [F (4, 132) = 7.32, $p < .001$, $\eta_p^2 = .18$] and a significant linear contrast over the learning blocks [F (1, 47) = 20.61, $p < .001$, $\eta_p^2 = .31$]. Further, there was a significant main effect of learning block [F (1.24, 40.84) = 100.10, $p < .001$, $\eta_p^2 = .75$][18] and a significant linear decrease in search times [F (1, 47) = 227.08, $p < .001$, $\eta_p^2 = .83$] across the blocks.

In order to ascertain whether there were differences in learning as a function of trait anxiety, a mixed-model ANCOVA was performed, with learning block (1–5) as the within-subjects factor and STAI-T as the continuous predictor. Results revealed no main effect of anxiety group or interaction with learning accuracy [main effect: F (1, 46) = 3.18, $p = .081$, $\eta_p^2 = .07$; interaction: F (4, 128) = 1.11, $p = .71$, $\eta_p^2 = .02$]. Similarly, there was no main effect of anxiety group or interaction with search times [main effect: [F (1, 46) = 0.85, $p = .36$, $\eta_p^2 = .02$; interaction: F (1.23, 39.20) = 0.19, $p = .19$, $\eta_p^2 = .05$][19]. As was the case in Experiment 1, trait anxiety did not affect the ability to form spatial-contextual associations of targets within scenes, therefore providing an appropriate baseline to assess subsequent attentional orienting.

[18] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(9) = 187.29$, $p < .001$. Greenhouse-Geisser correction was applied ($\varepsilon = 0.32$). Corrections were applied to interactions with trait anxiety.

[19] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(9) = 183.13$, $p < .001$. Greenhouse-Geisser correction was applied ($\varepsilon = 0.32$). Corrections were applied to interactions with trait anxiety.

Orienting Task

A mixed-model ANCOVA was conducted on accuracy scores (percent correct), with within-subjects factors of validity (valid, invalid) and face emotion (fearful, neutral), and the continuous predictor of trait anxiety. The accuracy analysis revealed a significant main effect of validity [F (1, 46) = 6.08, p = .017, η_p^2 = .12], with a modest increase (5%) in accuracy on valid compared to invalid trials [mean ± *SEM;* valid: 76.3%, ± 0.9%, CI = (74.5, 78.2) invalid: 71.7%, ± 0.9%, CI = (69.9, 73.5)] (Figure 3-6B). The increased accuracy on valid trials therefore reflects a similar effect size to that found in Experiment 1. There were no further main effects or interactions (all p's > .17).

As in Experiment 1, separate analyses were conducted using EPQN and BDI scores to examine whether threat distraction emerges when taking into account neuroticism and depression. The Shapiro-Wilk test revealed that both EPQN and BDI scores were not normally distributed (p < .001 for both). A log transformation failed to normalise both sets of scores (p < .001 for the EPQN*; p* = .002 for the BDI). Therefore, the non-parametric Mann-Whitney U test was conducted on target validity × face emotion conditions using high and low EPQN groups and BDI groups, created using a median split (median: EPQN = 2.0; BDI = 4.0). Results showed no significant differences between high and low EPQN groups (all p's > .096), and no significant differences between high and low BDI groups (all p's > .14).

Finally, an ANCOVA was conducted using state anxiety scores. Results revealed a significant main effect of validity [F (1, 46) = 5.24, p = .027, η_p^2 = .11]. No further main effects or interactions were found (all p's > .29).

Reaction times were compared for correct trials. A mixed-model ANCOVA showed no significant main effects or interactions (all p's > .15).

Memory Task

The mean distance between the original and indicated key location was 183.78 pixels (*SD* = 77.54). Participants' confidence ratings varied in accordance with the mean distance between their response and the key location so that they became less confident as their accuracy decreased (Figure 3-7B).

Similar to Experiment 1, a mixed-model ANCOVA was conducted to assess whether target validity and distractor emotion from the Orienting task affected subsequent explicit recall, with within-subjects factors of validity (valid, invalid) and face emotion (fearful, neutral), and the STAI-T as the continuous predictor. Results revealed a significant interaction between validity and STAI-T [F (1,46) = 4.22, p = .045, η_p^2 = .08], as well as a significant interaction between emotion and STAI-T [F (1,46) = 4.05, p = .050, η_p^2 = .08]. To clarify the first interaction, separate correlations were computed between STAI-T and the mean distance for scenes with valid key locations and for scenes with invalid key locations in the preceding Orienting task. This revealed a significant positive correlation between anxiety and distance for valid scenes [r = .29, p = .049], suggesting that higher anxiety levels were associated with poorer recall on scenes that re-affirmed memories via re-exposure in the Orienting task[20]. The second interaction was similarly explored by correlating the STAI-T with the mean distance for scenes that previously contained fearful face distractors and for scenes that previously contained neutral face distractors. This revealed a significant positive correlation between anxiety and mean distance for scenes previously associated with fearful face distractors [r = .36, p = .013][21]. These results indicate that participants with higher levels of anxiety exhibited poorer explicit recall for scenes previously containing threat. Finally, paired samples t tests confirmed that there was no significant

[20] To better delineate the size of the effect, for every 10 points on the STAI-T, there was an approximate 20-pixel increase in mean distance between the actual and indicated key locations.
[21] For every 10 points on the STAI-T, there was an approximate 50-pixel increase in mean distance.

difference in recall between scenes in which the key was absent and scenes in which they key was present in the Orienting task [t (47) = -0.81, p = .43].

As in Experiment 1, I computed the incidences in which participants incorrectly indicated that the target location was in the quadrant previously occupied by the distracting face versus in either of the other two remaining incorrect quadrants. A comparison of these quantities revealed no significant differences in the quantity of errors occurring in the quadrant of the face and the average quantity of errors occurring in the remaining two quadrants [t (47) = 0.88, p = .71]. Further, STAI-T did not significantly correlate with these quantities (all p's > .68). Similar to results of Experiment 1, these results indicate that the location of the distractor faces did not affect participants' explicit memories.

Finally, recall of the distractor faces was at chance level (50% accuracy). It can therefore be deduced that participants were unaware of the emotional valence of the faces across trials. However, these results may alternatively indicate that participants simply did not perceive the emotional expressions, thus rendering it difficult to draw a clear conclusion regarding the awareness of distractor emotion.

Dot-probe Task

The dot-probe task was analysed using ANCOVA, with word valence (threatening, neutral) as the within-subjects factor and STAI-T as the continuous predictor. This analysis approach was in line with previous studies using the dot-probe task (Salemink et al., 2007). Results revealed no significant main effects or interactions (all p's > .77). This suggests that participants in the current study did not exhibit an attentional bias to threatening stimuli in the dot-probe task.

Threatening	588.73 (± 9.99)
Neutral	591.20 (± 10.57)

Table 3-3: Results from the dot-probe task. Mean RTs for threatening and neutral words are shown with *SEM* in parentheses. There was no significant difference in RTs for threatening and neutral words.

3.3.4 Interim Discussion

Results from Experiment 2 revealed a main effect of validity, indicating that all participants were more accurate in detecting targets in previously learned locations. However, in contrast to Experiment 1, results showed no effect of emotion or modulations by state or trait anxiety, or by depression and neuroticism. Taken together, the anxiety-related distraction effects observed in Experiment 1 were eliminated when the ISI was shortened to 200 ms.

Results of Experiment 1 are in line with The Attentional Control Theory (Eysenck et al., 2007), which posits that anxiety is marked by an impaired balance between bottom-up exogenous attention and top-down endogenous attention, with the former receiving exaggerated priority. That is, anxious individuals exhibit greater influence of the stimulus-driven system coupled with deficient top-down control, resulting in impaired goal fulfilment and task performance. However, while findings of Experiment 1 demonstrate such distorted weighting, the differing results in Experiment 2 highlight the importance of considering the time course of threat disruption. When temporally proximate to task-relevant targets, task-irrelevant threatening stimuli no longer affect task performance and modulations by individual differences in anxiety disappear. Instead, the significant validity effect indicates that memories were successfully employed to guide attention.

Taken together, these findings suggest that when the time between distractor and target is brief, all participants, regardless of anxiety level, are able to suppress threat distraction and thereby efficiently employ memory cues.

In addition to results in the Orienting task, results in the Memory task also differed between the two studies.[22] While Experiment 1 showed no evidence of carry-over effects of previous validity or distractor emotion, Experiment 2 instead revealed that participants with high levels of trait anxiety exhibited diminished explicit recall for scenes previously associated with valid key locations in the Orienting task. Moreover, high anxious participants also showed poorer recall for scenes previously containing fearful face distractors. As all participants, regardless of anxiety level, showed validity effects in attentional orienting, the findings of impaired explicit recall in anxious participants for previously valid scenes suggest an anxiety-related dissociation between implicit and explicit memory systems, with the former spared and the latter impaired.

3.4 Discussion

The pair of studies investigated the effect of emotionally salient distractors in the context of memory-guided attentional orienting, and how this is affected by trait anxiety. The adapted memory-guided orienting paradigm allowed for the assessment of anxiety-related threat distraction within the context of another, endogenous, driver of attention and the relative pull of these signals on attention, indexed by task performance. For this purpose, distracting fearful and neutral face stimuli were incorporated into a speeded target detection task, in which memory cues were presented simultaneously with the task-irrelevant faces. Further, the use of long and short

[22] The mean distance, averaged across participants, in memory recall did not significantly differ between the samples of the two studies [t (78) = 1.33, p = .19, d = 0.30, CI= (-11.80, 59.37)].

ISIs over two studies enabled the investigation of the time course of threat distraction, i.e. the stage at which anxiety-related threat biases manifest.

Results of Experiment 1 showed that fearful face distractors disrupted task performance on a subsequent target detection task significantly more than neutral face distractors. Importantly, the extent to which fearful faces were more disruptive to task performance than neutral faces was positively correlated with trait anxiety scores. Thus, the performance of participants who scored highly on a self-report measure of trait anxiety was disproportionately disrupted by fearful versus neutral face distractors, compared with low trait anxious participants. This is consistent with previous literature demonstrating that anxious individuals more readily detect threat and show subsequent impairment in disengaging from such threat (Cisler & Koster, 2010; MacLeod & Mathews, 2012). Meta-analyses of previous studies have similarly reported such attentional biases toward threatening stimuli (Bar-Haim et al., 2007), using paradigms such as the dot-probe task (MacLeod et al., 1986; Mogg & Bradley, 1998). The current paradigm expands on these findings, showing that, when collectively considering myriad sources, threat biases receive greater weighting than memory cues, as a function of trait anxiety. Fearful faces, which signal an impending threat, therefore captured disproportionate attentional resources in the high anxious group, detracting from adaptive task performance. These findings demonstrate that, at long ISIs, memories do not compensate for threat disruption, thereby highlighting the potency of threatening stimuli in directing attention in anxious individuals.

However, when the ISI was shortened in Experiment 2, i.e. when the time between memory cue and target was reduced, the disruptive effect of threatening distractors and the modulation by trait anxiety was no longer evident. Instead, all participants exhibited efficient use of endogenous memory cues to facilitate target detection.

The direct comparison of long and short ISIs suggests that anxiety-related threat distraction is only evident over longer intervals.[23] That is, trait anxiety is associated with impaired distraction by fearful faces only when the target is presented after a long delay. This relatively long delay in Experiment 1 between the presentation of the cue scene, containing the face distractor, and the target presentation indicates that any additional distraction effect of fearful compared with neutral faces would have had to persist across this delay period in order to influence target detection. As the fearful face was presented for only 100 ms, precluding overt eye movements and explicit recognition, the observed disruption to subsequent task performance was not contingent on the continued presence of a threatening stimulus, and suggests that anxious participants continued to engage mentally with the fearful faces over an extended period of time. In contrast, the absence of comparable results in Experiment 2 indicates that the brief duration between cue and target hindered the appearance of threat effects. Taken together, results of both experiments suggest that the disruption of task performance by threat is contingent on sufficient time between the appearance of threat and the use of memories to guide attention. Thus, the recruitment of memories may operate at an earlier time point and may be initially immune to effects of salient distractors. The highly rapid time course at which memory-guided attention influences target detection is corroborated by results of Summerfield et al. (2006), showing that the cue scene facilitated detection of a target occurring at a 100-ms SOA.

As only the ISI was altered between studies, the appearance of the distractors coincided with the appearance of the cue scene in both studies, i.e. at the point at which memories were

[23] The variable ISI compared to the fixed ISI may have had additional, unintended effects, as the unpredictability created by the variable ISI range may have exacerbated threat effects (Shapiro & Lim, 1989). Unpredictable or uncontrollable circumstances can increase anxiety levels (Chorpita & Barlow, 1998; Grillon, 2002), thereby potentially exacerbating attentional biases to threat in the current study. This possibility is speculative and would require further research.

cued. As such, the differential effects of threat between the studies cannot have occurred at this early stage of memory cueing. Instead, the discrepancy in results between the two methodologies suggests that threat disrupted the use of memories during the delay period, when memories must be kept active until the appearance of targets. When sufficient time is provided, allowing anxious participants to process threatening distractors, the recruited memories lose out against the salient distractors. However, with short delays, memories were used effectively. That is, the threat distraction that plagues anxiety may be reliant on sufficient time for threat processing when a competing influence on attention is available.

The implication that threat is not processed automatically and instead competes for available resources with other drivers of attention counters cognitive models that posit the automaticity of threat processing in anxious individuals (Beck & Clark, 1997; Holmes, Nielsen, Tipper, & Green, 2009; Mogg & Bradley, 2018). Current results underscore the need to consider other cues available for attentional processing, which may diminish or entirely eliminate threat effects. The ability of memories to withstand threat disruption at a short ISI may be due to the increase in perceptual load as a consequence of the introduction of memory cues. The reduction in ISI and the consequent rapid successive appearance of stimuli may have placed greater demands on perceptual processing. Previous studies have shown that task-irrelevant fearful faces only exert disruptive effects in anxious participants under conditions of low perceptual load. Greater amygdala activation in response to task-irrelevant fearful faces has been shown to be contingent on sufficient processing resources offered by tasks of low perceptual load in anxious participants, mirroring behavioural effects of task disruption by threat exclusively under low perceptual load conditions (Bishop, Jenkins, & Lawrence, 2007). Thus, when task-relevant information depletes attentional resources, distracting threat fails to capture attention, challenging

notions of privileged, preattentive processing of threatening stimuli. Instead, under conditions of high perceptual load, anxious individuals are unaffected by threatening distractors and thereby exhibit similar attentional patterns to their low anxious counterparts (Sadeh & Bredemeier, 2011). The long ISI range in Experiment 1 may have placed fewer demands on attentional resources, allowing threatening distractors to influence orienting.

Studies by Forster et al. (2014) and by Schuyler et al. (2014) provided evidence of an anxiety-related threat disruption unique to long ISIs. While the current set of results corroborates these findings, the ISIs used in the current studies were comparatively shorter, thus shifting the responsivity and recovery windows. The earlier time windows in the current study may be due to the nature of the threatening stimuli, which were task-irrelevant and located in a distracting location relative to the competing spatial memory. In contrast, the threatening stimuli in previous studies were presented in isolation and for longer durations, thus necessarily demanding awareness and processing resources. These conditions may have potentially set in motion deliberate avoidance mechanisms in anxious participants, which operates at later processing stages (Koster et al., 2006), thus resulting in delayed anxiety-related threat disruption. Despite different time windows defining responsivity and recovery, results reveal the significance of considering threat disruption over a longer time course as a therapeutic avenue for clinical interventions. Given that even simple threatening stimuli of the type used here are sufficiently salient to disrupt the usage of memories in orienting attention in anxious individuals, strategies to mitigate the downstream effects in the lives of anxiety patients are much needed. Such processes may well underlie the functional impairments associated with anxiety, such as lapses in concentration and impoverished performance on daily tasks.

The explicit memory task yielded differing results between studies. While there were no anxiety-related effects in Experiment 1, results in Experiment 2 revealed differential recall as a function of trait anxiety. That is, contrary to findings of a validity effect across participants, i.e. independent of anxiety, participants with high levels of anxiety showed diminished accuracy for scenes that contained a valid key location in the preceding Orienting task. That is, while anxious participants were effectively able to recruit memories to guide attention, they subsequently could not explicitly access these memories as readily. These findings suggest that the dissociation between implicit and explicit memory functions may be an important consideration in understanding how anxiety modulates the use of memory cues. Previous studies examining the role of stress have demonstrated differing effects of stress on explicit memory, with some showing a strengthening of explicit memory by stress, particularly when memories include emotional material (Buchanan & Lovallo, 2001), and others showing stress-induced impairments (Newcomer et al., 1999). Instead, there is greater consensus that stress does not impact (Kirschbaum, Wolf, May, Wippich, & Hellhammer, 1996), or even facilitates (Luethi, Meier, & Sandi, 2008), implicit memory. As stress and anxiety are intertwined, with an underlying crossover in the neural structures implicated in both anxiety and stress responses (Shin & Liberzon, 2010), the current results supplement previous findings by showing a similar discrepancy between anxiety-related effects on explicit versus implicit memory systems. Moreover, while the appearance of threatening distractors did not impede the use of memories in orienting attention at short ISIs, anxious participants nonetheless showed poorer recall for scenes that previously contained fearful face distractors. These findings suggest that while the presence of task-irrelevant threat did not detract from recruitment of implicit memories at a shorter time scale, they nonetheless interfered with the explicit recruitment of these memories. That is, the adverse impact of threat did not occur at early processing stages but instead exhibited a delayed

and prolonged impact, thus affecting explicit retrieval of memories. Taken together, the use of a short ISI therefore prevented threat disruption and instead enabled implicit memories to be successfully employed to fulfil task goals. Yet, the effects of threat emerged over an extended time window, thus demonstrating a delayed effect of threat in anxious individuals. Though the current results indicate that the dissociation between implicit and explicit memory systems may be significant in anxiety, further work is required to delineate anxiety effects on both implicit and explicit memories.

Consistent with previous studies (Patai et al., 2012), both studies yielded a significant effect of target validity, with greater accuracy for targets that appeared in the expected (learned) location than targets appearing in a location that was incongruous with previous learning. Thus, participants in both studies were able to recruit long-term memories to guide attention to targets. These results contribute to the extant body of research on memory-guided orienting. Summerfield et al. (2006) compared a visual orienting task, using exogenous spatial cues, to the memory-guided paradigm. Their findings of a stronger behavioural validity effect in the memory paradigm demonstrates the strength of memories in directing attention through their provision of rich contextual information. The authors posited that endogenous memory cues might be a more ecologically valid mechanism by which to guide attention in complex scenes, as these cues contain both spatial memories and semantic contextual information. In contrast, the reduced validity effect derived from visual orienting may be attributable to the inherent complexity of naturalistic scenes, within which myriad competing stimuli encumber perceptual processing. Current results, however, demonstrate the importance of considering the emotional significance of these transient perceptual events. The fearful faces in Experiment 1 garnered attentional resources, despite the complex naturalistic backdrop, and received greater weighting compared to

memory cues. Instead, in Experiment 2, these fearful faces did not impair the recruitment of memories over a shorter time scale, revealing the strength of memory cues in directing attention. Taken together, the relative contribution of bottom-up visual events and top-down memory retrieval in orienting attention is best addressed when considering stimuli properties, such as their emotional salience, as well as inter-individual differences, such as trait anxiety.

The dot-probe task was administered as a gauge of concurrent validity, i.e. whether attentional biases measured in the context of competing memory signals are comparable to biases measured in isolation. However, results showed no evidence of attentional biases to threatening words and no modulations by trait anxiety. Previous studies using the probe task have yielded inconclusive results. The discrepant findings may in part be due to the stimuli durations, which are typically approximately 500 ms, leaving unclear the attentional patterns occurring prior and subsequent to this snapshot; in fact, some studies found that attentional biases toward threat are only evident at shorter durations, after which an attentional avoidance is observed (Bradley, Mogg, Millar, et al., 1997; Clark & Wells, 1995; Cooper & Langton, 2006). The lack of biases in the current study may therefore be due to the stimulus duration of 500 ms. Additionally, the use of words as stimuli may have hampered anxiety-related effects. Pishyar, Harris, and Menzies (2004) compared a verbal and pictorial version of the task in a sample of socially anxious individuals and only found a threat bias in the latter version. This may be attributable to faces being endowed with comparatively greater ecological validity, resulting in more efficient processing. Instead, words require an additional step of semantic processing. Further, whereas a threatening face unambiguously connotes threat, the connotations of words may be more susceptible to individual differences in interpretation.

The memory-guided orienting paradigm and current set of results pave the way for future research. A fruitful avenue would be to manipulate the distractor duration in order to determine whether threat distraction is contingent on awareness, i.e. whether the findings hold when the presentation times of the faces are extended to allow for conscious recognition. Further, the distracting stimuli in the current study were solely neutral and threatening faces, with the latter's depicted emotion necessarily rendering them more perceptually salient. This precludes a clear distinction between the roles of bottom-up perceptual salience and higher-order emotional salience in eliciting attentional capture. It thus cannot be deduced whether anxiety is marked by enhanced distraction to exclusively emotional material or more generally to perceptually salient stimuli. Future research should therefore apply salient non-emotional stimuli to the paradigm in order to clarify whether emotional content is a prerequisite for anxiety-related distraction.

The current set of studies offer a new approach into the investigation of cognitive biases characterising trait anxiety. Pitting exogenous threatening material against endogenous memory cues offers a more comprehensive account of how threat directs attention in trait anxious individuals. In addition to the ecological validity accorded by modelling multiple and competing drivers of attention in this paradigm, the use of complex naturalistic scenes further enhances the paradigm's realistic quality. Studying attentional orienting in contexts closely resembling our everyday environments provides a more accurate depiction of how we filter through rich environments to direct attention toward relevant information. Moreover, the application of long and brief ISIs enabled a clearer distinction of the underlying temporal properties of attentional biases, revealing the contingency of threat biases on the timing between cue and target. Taken together, the current results shed light onto the extent of threat distraction in anxiety and stimulate further research in delineating these attentional biases.

4 Modulations of Anxiety-Related Attentional Biases by Age

Healthy ageing is characterised by a positivity bias, which describes a greater attentional focus on positive information. However, anxiety is nonetheless prevalent in late adulthood. Thus, the emotional memory-guided orienting paradigm was used in a sample of high and low anxious older adults in order to examine how the recruitment of memories competes with anxiety-related attentional engagement with threat. The paradigm not only provides an account of attentional biases but also enables investigations of learning and memory. In addition to assessing effects of anxiety within the older adult sample, changes across age were examined via comparisons with the young adult sample from Experiment 1 in Chapter 3. Results showed that anxious older adults exhibited impaired recruitment of spatial long-term memories when presented with fearful face distractors. These findings reveal the persistence of anxiety-related attentional biases to threat across age. The study also revealed more puzzling results. In particular, non-anxious participants showed no use of memories, regardless of distractor emotion. Taken together, the findings reveal the potency of threat biases that persist into late adulthood and also underscore the need for continued research to supplement the limited extant research regarding anxiety in older adults.

4.1 Introduction

Research on healthy ageing has shown that 'successful ageing' is linked to a heightened attentional focus and a corresponding enhanced memory of positive, relative to both neutral and negative, information (Reed et al., 2014). This phenomenon, termed the *positivity bias*, therefore suggests that emotional well-being is spared in the ageing process and operates independently of age-normative cognitive decline. The socioemotional selectivity theory posits that the bias stems from the perception of limited remaining lifetime, which causes a shift in older adults' motivational goals toward a greater focus on positive information as a means of optimising well-being (Carstensen, 1992; Mather & Carstensen, 2005; Reed & Carstensen, 2012; Spaniol, Voss, & Grady, 2008). The theory contends that enhanced emotion regulation underlies these shifts in processing (Carstensen, 1992), allowing for efficient dismissal of negative information (Gross et

al., 1997). Further theories posit that learning and practice, accumulated over the lifetime, have strengthened emotion regulatory capacities that equip older adults with efficient strategies in coping with emotionally laden situations (Blanchard-Fields, 2007; Scheibe & Blanchard-Fields, 2009). Studies using divided attention tasks have shown that the positivity bias is reliant on sufficient cognitive resources, thereby confirming the underlying role of emotion regulation (Brassen, Gamer, & Büchel, 2011; Knight et al., 2007). Moreover, studies using mood induction reveal the unique role of emotion regulation in the late-life positivity bias, distinguishing processing in older adults from that in younger adults. That is, while attention and memory in younger adults are generally guided by current mood states and are therefore products of mood, they serve as catalysts for mood in older adults (Bradley, Mogg, & Lee, 1997; Matt, Vázquez, & Campbell, 1992). Isaacowitz, Toner, Goren, and Wilson (2008) showed that while young adults exhibited preferential gaze to stimuli congruent with their moods, older adults instead showed a reversed mood-incongruous pattern for negative moods. Thus, older adults directed their gaze to positive information when in a negative mood, thereby strategically improving their mood states.

Alternatively, other theories have instead attributed the late-life positivity bias to age-normative neural changes. Specifically, these theories assert that the positivity bias is a by-product of age-normative decline in neural functioning, particularly in regions governing emotional processing (e.g. amygdala). Older adults showed decreased amplitudes of the late positive potential (LPP), an ERP elicited in response to oddball valenced stimuli during an evaluative categorisation task, yet showed intact subjective experiences of emotional material. These findings reveal a decrease in reactivity to negative stimuli, on account of diminished autonomic nervous system arousal, rather than an increase in attention devoted to positive information (Wood & Kisley, 2006). Similarly, older adults exhibited decreased autonomic

reactivity (Tsai, Levenson, & Carstensen, 2000), as well as reduced amygdala responses, to negative images (Mather et al., 2004). This decrease in neural responsivity to negative stimuli resultantly manifests as a positivity bias at the behavioural level. Thus, the age-normative reduced activation in 'emotion regions', particularly in response to negative information, may account for the positivity bias, rather than overt regulatory strategies of increased attention to positive stimuli.

Despite the evidenced positivity bias in late adulthood, anxiety disorders constitute the most common mental disorder in older adults, with reported prevalence rates of approximately 10–15% in individuals aged 65 years and above (Bryant, Jackson, & Ames, 2008; Wolitzky-Taylor, Castriotta, Lenze, Stanley, & Craske, 2010), surpassing rates of severe cognitive impairment and dementia (Beaudreau & OHara, 2008; Regier et al., 1988). Although being under-diagnosed (Calleo et al., 2009), anxiety causes a slew of adverse effects in older adults, such as increased risk of cardiovascular disease, stroke, and decline in cognitive function (Andreescu & Varon, 2015) and shows high comorbidity rates with depression (Richardson, Simning, He, & Conwell, 2011). Moreover, non-clinical, high trait anxiety also poses severe problems for older adults, with prevalence rates as high as 50% (defined as adults exhibiting at least one symptom of anxiety) (Schaub & Linden, 2000).[24]

However, despite these figures, there remains a dearth of research devoted to understanding anxiety in late adulthood. In particular, considering the evidence of the positivity bias, it is plausible that anxiety-related attentional biases to threatening information are modulated by age. On account of their reinforcing role in anxiety, attentional biases to threat are

[24] Prevalence rates of anxiety in an older adult population are difficult to pinpoint, as they are subject to variations in functional ability, medication use, and comorbid medical conditions that characterise the population (Ayers, Sorrell, Thorp, & Wetherell, 2007). Moreover, the co-occurrence of anxiety symptoms and physical symptoms renders clear isolation of anxiety symptomatology difficult (Jeste, Blazer, & First, 2005).

a key target of treatment protocols. It is therefore important to clarify the unique attentional distortions that characterise anxiety in late adulthood, rather than merely extrapolate findings from young adults and apply corresponding treatments. Current treatments for anxiety are primarily tailored to young adults and fail to take into account changes in symptomatology across age. Treatments are rarely sought by anxious older adults, with roughly 5% undergoing psychological treatment and 4% receiving psychopharmacological treatment (Hendriks, Oude Voshaar, Keijsers, Hoogduin, & Van Balkom, 2008). Delineating cognitive distortions that mark anxiety in older adults is therefore a key area of research and can provide important insight into treatment protocols.

The few studies devoted to investigating attentional biases in anxious older adults have yielded mixed findings. Lee & Knight (2009) examined how trait anxiety modulates the established positivity bias. By using subliminal (50 ms) and supraliminal (1500 ms) presentations of angry, sad, and neutral faces in a dot-probe task, the authors were able to tap into vigilance-avoidance attentional patterns. Results revealed that all older adults, regardless of anxiety level, showed a vigilant-avoidant response to angry faces, i.e. with initial attention toward these faces followed by avoidance. This finding reflects the biological significance of detecting threatening stimuli, which is independent from anxiety and age-related decline. However, trait anxiety modulated attentional responding to sad faces; moderately trait anxious older adults showed a vigilant-avoidant response when viewing sad, relative to neutral, faces. Thus, individuals with lower levels of anxiety possess a positivity bias, allowing them to avoid aversive stimuli, yet this bias wanes with increasing anxiety. The discrepancy in findings for angry versus sad faces may reflect the greater threat posed by the former, thus attracting attention independently of individual differences. Instead, sad faces do not possess comparable levels of threat, as compared to angry

faces, and therefore attracted attention exclusively in anxious participants, potentially on account of a diminished positivity bias. Interestingly, when using a verbal dot-probe task, the authors found that only high anxious older adults displayed an avoidant-vigilance attentional pattern. These results may indicate that through practice over the course of their lives, anxious adults developed a tendency to avoid threatening words. However, with longer stimulus durations, this avoidance is supplanted by vigilance such that anxious older adults redirect their attention to threatening words, plausibly reflecting worrying, a cognitive product of anxiety that is used to deal with threat-induced arousal (Hazlett-Stevens & Craske, 2003).

Corroborating these findings of threat-related attentional biases, Price, Siegle, & Mohlman (2012) found that high-worry older adults showed greater task interference by threatening, compared to neutral, words in the emotional Stroop task. However, they showed task facilitation by positive words, suggesting that anxiety may also be marked by a dismissal of positive information.

Contrary to results of modulations by trait anxiety, Fox and Knight (2005) instead showed that only state anxiety predicted threat biases, independent of trait anxiety, when using the dot-probe task. While the authors had predicted that high levels of combined state and trait anxiety would elicit the greatest biases, the authors speculated that results may be explained by the intensity paradox (Jones, Stacey, & Martin, 2002). This posits an elimination of an attentional bias in the presence of very high levels of anxiety due to an increased focus on the high intensity state of anxiety, which in turn causes inhibition of allocated attention to relatively minor threats. The combined high state and trait anxiety seemed to have therefore inhibited sufficient processing of the semantically threatening words.

While these studies suggest that attentional biases to threat are resistant to age-normative cognitive decline, other studies have failed to find evidence for anxiety-related biases. In a sample of clinically anxious older adults, Mohlman, Price, and Vietri (2013) found no evidence of differential attentional processing of both negative and positive words as a function of generalised anxiety disorders.

Results regarding the nature of attentional biases have evidently been mixed. The discrepancy in results across studies may in part be attributable to the heterogeneity of cognitive abilities in late adulthood. Different rates of cognitive and neural decline create extensive inter-individual variability, rendering it difficult to characterise attentional patterns in anxiety in older adults (Mohlman, 2013). Further, differing results may stem from methodological variations across studies, including the tasks employed, stimuli durations (subliminal or supraliminal), stimuli modality (pictures or words), and participants' levels of anxiety (Price et al., 2012). Given the overall dearth of research regarding anxiety-related attentional biases in late adulthood and the inconsistencies between the few extant studies, adopting a novel approach to studying these biases may provide clarity. The adapted emotional memory-guided orienting paradigm, which showed threat distraction effects in anxious young adults (see Chapter 3), was used to examine whether threatening distractors impede the use of endogenous memory cues to guide attention in trait anxious older adults. As this task takes into account memory cues as drivers of attention, the current study provides a comprehensive and thereby ecologically valid assessment of anxiety-related attentional biases to threat in late adulthood.

Moreover, the task not only taps into threat biases, but also provides an examination of potential modulations in learning and memory as a function of anxiety. In addition to being plagued by distorted attention to threat, anxious older adults exhibit a reduction in cognitive

function, extending beyond processing of exclusively emotional material and beyond age-normative decline. Anxiety is thus a risk factor for mild cognitive impairments and Alzheimer disease (Palmer et al., 2007). However, the relationship is bidirectional as cognitively impaired older adults report greater symptoms of anxiety (Beaudreau & O'Hara, 2008). The anxiety-related impairments are postulated to result from excessive cognitive load via the preoccupation with internal and external sources of threat, cumbering the attentional system and leaving few resources to devote to other tasks (Eysenck et al., 2007). A study by Beaudreau and O'Hara (2009) assessed deficits in executive functions in both anxiety and depression and showed that inhibitory functions were impaired in anxious older adults, indexed by disruption on the non-emotional Stroop task. Moreover, comorbid anxiety and depression was associated with difficulties in shifting attention, as measured by the Symbol Digit Modality Test that requires participants to match specific numbers to geometric symbols. A further study in healthy older adults showed that anxiety was marked by a reduction in verbal memory recall (Yochim, Mueller, & Segal, 2013). This deficit was linked to poor initial learning resulting from difficulties in categorisation, i.e. sorting new information into categories so as to facilitate learning. Exacerbated anxiety-related memory decline has also been found in clinically anxious older adults (DeLuca et al., 2005).

As the paucity of research regarding attentional mechanisms in anxious older adults has yielded mixed results, the current study used the memory-guided orienting paradigm incorporating fearful and neutral face distractors (see Chapter 3) to provide a novel measure of threat biases. In particular, the study aimed to assess how the recruitment of memories competes with anxiety-related attentional engagement with threat. While the positivity bias, and the corresponding enhanced emotion regulatory strategies, may serve as a buffer against the adverse

effects of threat, the anxiety-related cognitive impairments may impede the formation and subsequent use of memories in the interest of task achievement. In addition to attentional biases to threat, the memory-guided orienting paradigm enables assessments of learning and memory, therefore providing a comprehensive approach to investigate these competing effects. Moreover, in addition to within-subjects analyses of anxiety differences, the study also examined differences in threat distraction between older and younger adults via comparisons to Experiment 1 of Chapter 3. Comparisons were limited to Experiment 1, as the methodology was most similar to that used in the current study.

A previous study using a non-emotional version of the memory-guided paradigm in healthy older adults showed that while explicit memory performance was impaired, implicit memory was spared from age-related cognitive decline, as evidenced by a robust validity effect (Salvato et al., 2016). Thus, the distinction between implicit and explicit memory is important when investigating age-related changes in memory function. However, it should be noted that while evidence of decline in explicit memory with age has been consistently reported across studies, the degree of comparable deterioration of implicit memory remains equivocal (Kessels, Boekhorst, & Postma, 2005; Salvato et al., 2016; Smyth & Shanks, 2011). The current study therefore aimed to clarify these inconsistencies.

In line with results of the study by Salvato et al. (2016), using the memory-guided orienting task, I predicted that older adults with low levels of trait anxiety would exhibit a validity effect yet would show poor explicit memory recall, particularly compared to young adults. Moreover, in accordance with an age-normative positivity bias, I predicted that non-anxious older adults would show no interference by fearful face distractors. Specifically, the current study used the equivalent long ISI range as that used in Experiment 1 of Chapter 3. I

therefore postulated that this range would allow for sufficient time to execute an emotion regulatory strategy, with aversive faces consequently being readily dismissed.

In contrast, predictions for older adults with high trait anxiety were comparatively exploratory. Given the cognitive impairments that are associated with anxiety in late adulthood, I hypothesised that higher levels of anxiety would reveal greater learning difficulties of non-emotional spatial information, in line with the reported difficulties in categorising new information and suppressing distracting information due to inhibitory deficits. I further predicted that anxious older adults would show poorer explicit memory recall, in accordance with findings of poorer memory in anxiety (Delphin-Combe et al., 2016; Yochim et al., 2013). Moreover, the ruminations that mark anxiety may potentially interfere with overall task performance (Beaudreau & O'Hara, 2009; Beaudreau & O'Hara, 2008; Pietrzak et al., 2012). With regard to the role of threat, I predicted that fearful face distractors would have more disruptive effects on memory recruitment compared to neutral face distractors for all participants. However, this disruption by threat would be greater in high anxious, compared to low anxious, participants. Further, I hypothesised that the evidenced increase in emotion regulation and the associated positivity bias would equip anxious older adults with greater resistance to threat effects, compared to anxious younger adults.

4.2 Methods

4.2.1 Participants

Forty-eight participants, aged 60–79 years (mean age = 66.08, *SD* = 1.78; 29 females), were recruited through online adverts and local flyers. All participants had normal or corrected vision,

had no history of neurological or psychiatric illness, and were fluent in English. Participants gave their written informed consent and were compensated £10/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC-C1-2014-075).

Participants were recruited based on their State-Trait Anxiety Inventory Trait-scale Inventory (STAI-T; Spielberger, 1983) scores so as to ensure an adequate spread of trait anxiety levels. In particular, I used a cut-off score of 40 to distinguish between low and high anxiety, with scores of 40 and above signifying high anxiety. Recruitment was aimed at obtaining equal numbers of participants with high and low levels of anxiety.

Participants were primarily retired (34 participants), with the remaining participants either currently working (12 participants) or unemployed (2 participants). The average number of years of education achieved was 17 years, with most participants having obtained a postgraduate (17 participants) or undergraduate (10 participants) degree. Of the remaining participants, 9 participants received no qualification, 7 participants obtained a professional degree, 3 participants obtained A levels, and 2 participants obtained O levels. By comparison, the younger adults from Experiment 1 of Chapter 3 were undergraduate or postgraduate students. Thus, it is important to be aware of these differences in demographics between the older and younger samples.

4.2.2 Procedure

Participants attended two test sessions at the Department of Psychiatry at the University of Oxford, conducted 24 hours apart. In the first session, after reading the Participant Information Sheet and consenting to taking part, I administered the Addenbrooke's Cognitive Examination (ACE; Mathuranath, Nestor, Berrios, Rakowicz, & Hodges, 2000). This assessment, which

specifically measures the cognitive domains of orientation, verbal fluency, memory, language, attention, and visuospatial skills, is commonly used to determine mild cognitive impairment and dementia and is scored out of 100. The ACE was administered to detect, and therefore exclude, any participants that exhibited signs of cognitive decline. However, all participants obtained scores falling within the normal range (M = 92.11, SD = 5.97).

After the ACE, participants independently completed the STAI-T, and the BDI-II (Beck et al., 1996) on the online questionnaire platform Qualtrics (Qualtrics, Provo, UT). Results of questionnaires are shown in Table 4-1. As was done in my previous experiments, STAI-T scores obtained on the day of testing were used in analyses. Participants then completed the Learning task. This first session took approximately 2 hours. The following day, participants returned to complete the Orienting and Memory tasks, which were always completed in this order. After completing the Memory task, participants performed the dot-probe task in order to provide a direct comparison of attentional biases between this established paradigm and the novel memory-guided orienting paradigm. As was done in Chapter 3, the dot-probe task used valenced word stimuli. The second session took approximately 1.5 hours.

STAI-trait	38.15 (± 1.59)	20–67
STAI-state	31.87 (± 1.62)	20–73
BDI-II	8.04 (± 1.08)	0–29
EPQN	3.63 (± 0.51)	0–12

Table 4-1: Questionnaire results. Means are shown with *SEM* in parentheses and range on the far right.

4.2.3 Task

The Learning and Orienting tasks were based on those used in Experiment 1 of Chapter 3. As anxiety-related effects in the younger adult sample were evidenced in the context of long ISIs, I used the equivalent long ISI range in the current study. However, initial piloting showed that the target size used with the young adult sample resulted in insufficient accuracy levels and excessively lengthy experimental sessions in older adults. Thus, I increased the key size in both the Learning and Orienting tasks by 25%[25] (Figure 4-1A for the Learning task design and Figure 4-2A for the Orienting task design). The Memory task was based on that used in Experiment 2 of Chapter 3 and therefore included a face recall test. Finally, the dot-probe task was administered at the conclusion of the Memory task. Here, I similarly increased the size of dots by 25%.

The assignment of each scene according to the experimental conditions of target presence (present, absent), validity (valid, invalid), and face emotion (fearful, neutral) was counterbalanced across participants, resulting in eight versions of the task.

[25] The 25 % increase resulted in a key size of 18.75 × 36.25 pixels for the Learning task and 31.25 × 61.25 pixels for the Orienting task.

A

B

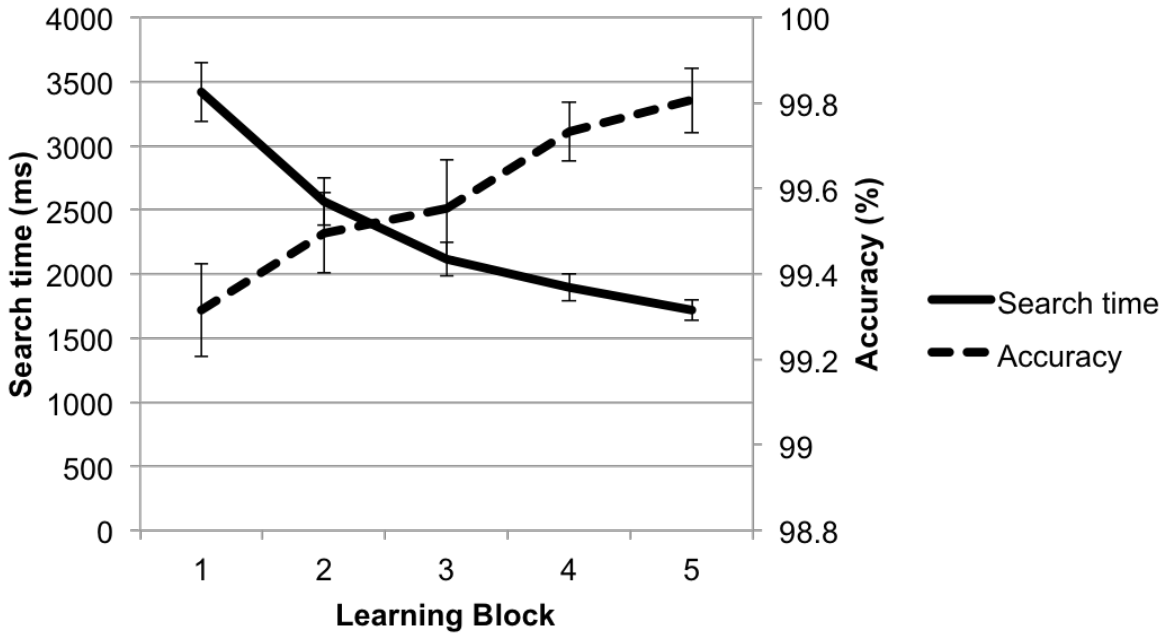
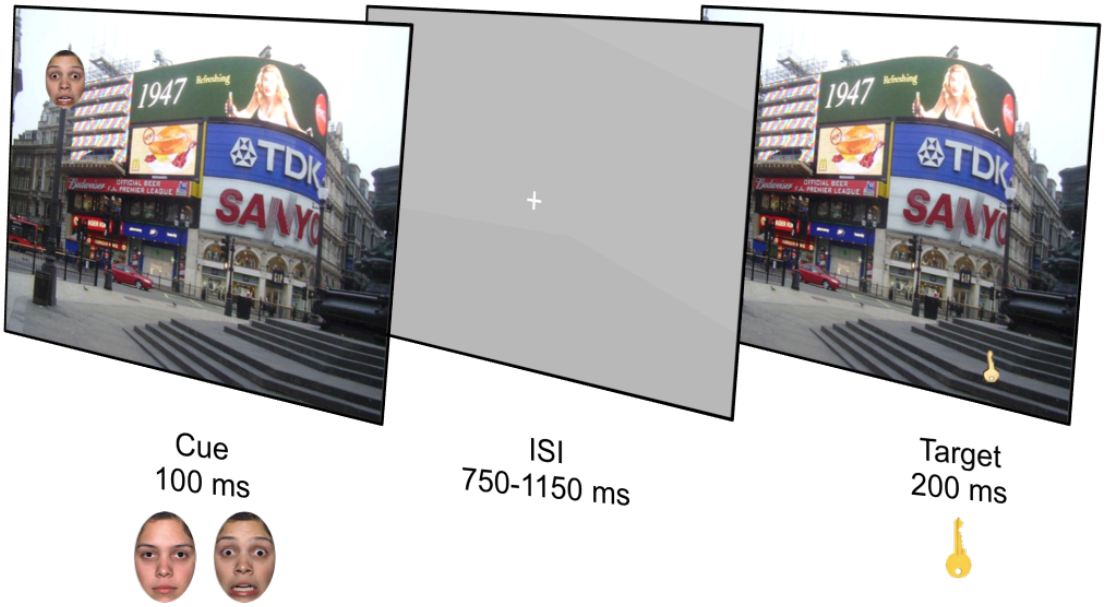
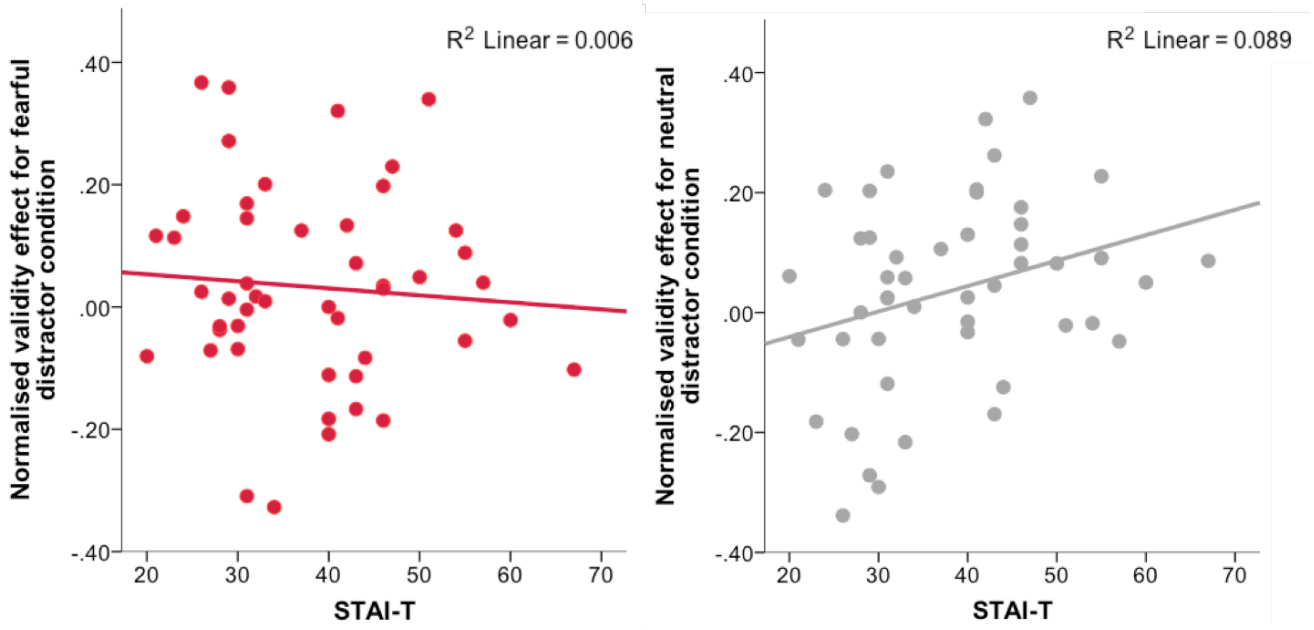


Figure 4-1: Learning task: results. (A) Participants overtly searched for keys, located in 1 of 4 quadrants, for 168 naturalistic scenes (three examples shown, red box, indicating key location, is included for illustrative purposes only). (B) Over the course of the learning blocks, participants became more accurate and quicker at detecting targets.

A


Cue
100 ms
ISI
750-1150 ms
Target
200 ms

B


R² Linear = 0.006
Normalised validity effect for fearful distractor condition
.40
.20
.00
-.20
-.40
20
30
40
50
60
70
STAI-T
R² Linear = 0.089
Normalised validity effect for neutral distractor condition
.40
.20
.00
-.20
-.40
20
30
40
50
60
70
STAI-T

C

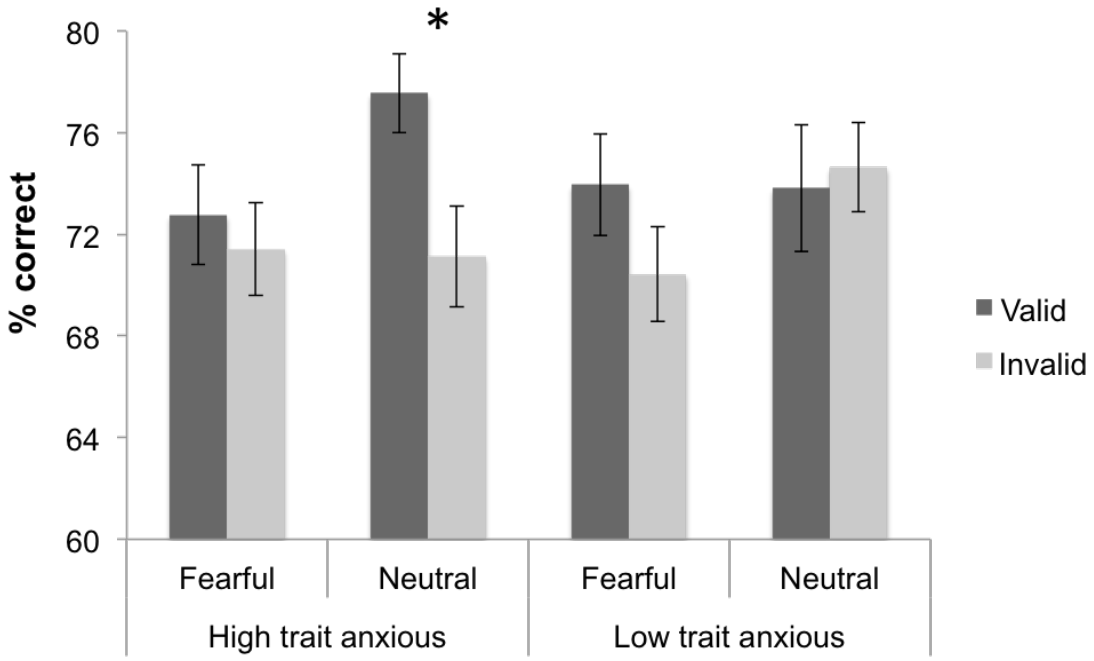


Figure 4-2: Orienting task: design and results. (A) Cue scenes containing either fearful or neutral faces were presented for 100 ms. After an ISI ranging from 750–1150 ms, target scenes, which presented the key on half the trials, appeared for 200 ms. (B) There was a significant positive correlation between STAI-T (*x*-axis) and the validity effect on neutral distractor trials (*y*-axis). (C) The high trait anxious older adults exhibited a significant validity effect for trials with neutral face distractors, while the low anxious older adults showed no validity effect for either emotion condition.

A

B

Figure 4-3*:* Memory task: design and results (A) Participants indicated the learned location of the key, followed by a confidence rating. (B) Mean distance (*y*-axis) from target location as a function of confidence ratings (*x*-axis). Mean distance decreased as confidence ratings increased. Error bars represent ±1 *SEM*.

4.3 Analysis

Analyses for the Learning, Orienting, and Memory tasks were identical to Experiment 1 in Chapter 3. Removal of individual raw RTs in the Orienting task resulted in the exclusion of 1.3% of trials.

Where the assumption of sphericity was violated, degrees of freedom were corrected using either Greenhouse-Geisser or Huynh-Feldt estimates of sphericity, depending on the ε value. All post-hoc tests were all conducted with Bonferroni correction. An alpha level of .05 was selected as the minimum point for rejection of null hypotheses.

For the dot-probe task, trials with errors were removed for each participant (mean of 0.6% across participants). For the remaining accurate trials, RTs below 200 ms or exceeding 3 standard deviations of individual means were excluded (mean of 1.4% across participants).

4.4 Results

Scores on the STAI-T ranged from 20 to 67, inclusive (M = 38.15, SD = 11.01) (Figure 4-4). These scores are similar to those reported in previous studies for this age group (Fox & Knight, 2005; Lee & Knight, 2009). The Shapiro-Wilk test (Shapiro & Wilk, 1965) revealed that the distribution of STAI-T scores did not significantly diverge from normal (p = .10).

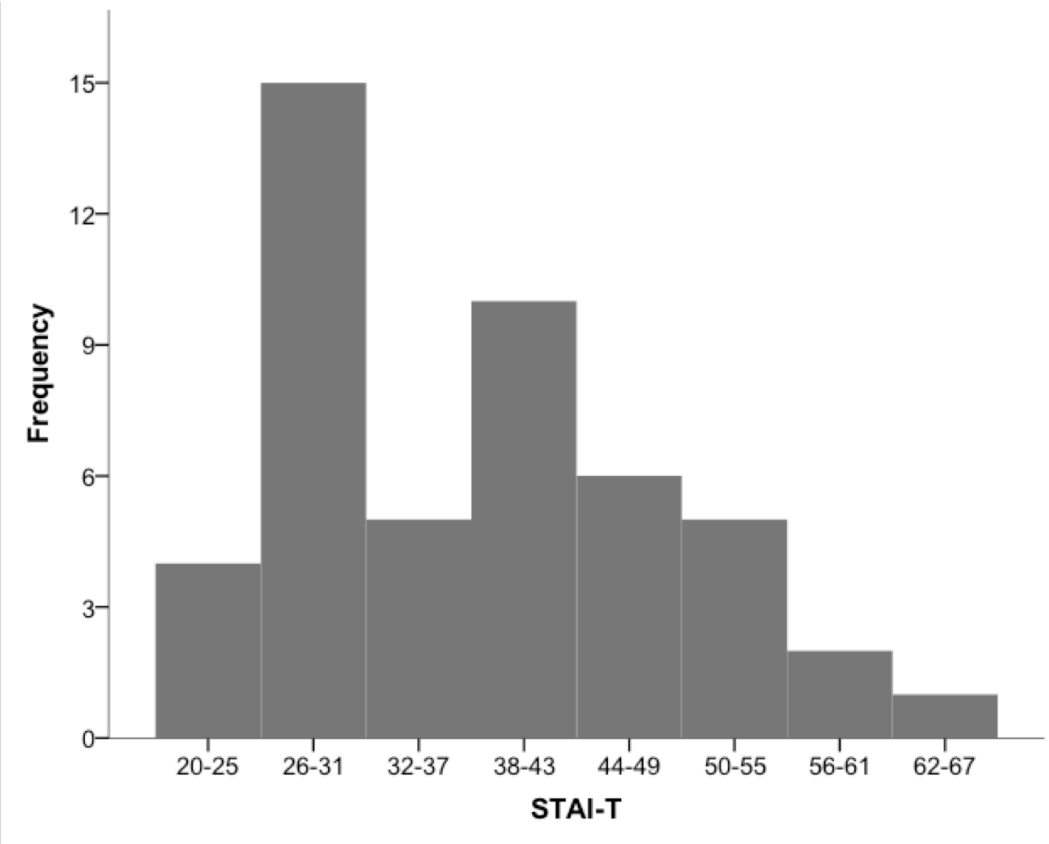


Figure 4-4: The spread of STAI-trait scores.

4.4.1 Learning Task

A circle with a radius of 50 pixels around the key defined the region within which responses were deemed accurate. Scenes for which participants did not locate the key in two or more blocks were excluded from further analyses. Fourteen participants did not locate the key in one scene and therefore data for the scenes were removed from further analyses for these participants. One additional participant did not locate the key in two scenes, resulting in the removal of these scenes from analyses for that participant.

There was an overall decrease in search times and an increase in accuracy across the five learning blocks, indicating that participants successfully learned the location of the keys in the scenes (Figure 4-1B). Accuracy for locating the target key was consistently high from the first learning block (accuracy, SD, range: 99.23%, 0.008, 0.03). ANOVAs testing for linear increases in accuracy showed a significant main effect of learning block [F (3.42, 157.16) = 6.04, $p < .001$, $\eta_p^2 = .12$][26] and a significant linear contrast over the learning blocks [F (1, 46) = 23.20, $p < .001$, $\eta_p^2 = .34$]. Further, there was a significant main effect of learning block for search times [F (1.60, 73.66) = 69.47, $p < .001$, $\eta_p^2 = .60$][27] and a significant linear decrease in search times [F (1, 46) = 89.34, $p < .001$, $\eta_p^2 = .66$] across the blocks.

In order to ascertain whether there were differences in learning as a function of trait anxiety, a mixed-model ANCOVA was performed, with learning block (1–5) as the within-subjects factor and STAI-T as the continuous predictor. Results revealed no main effect of STAI–T or interaction with learning accuracy [main effect: F (1, 46) = 0.03, $p = .87$; interaction: F (3.46, 159.34) = 0.77, $p = .53$].[28] For search times, there was a marginally significant main effect of STAI-T and a marginally significant interaction [main effect: F (1, 46) = 3.20, $p = .080$; interaction: F (1.69, 77.55) = 2.99, $p = .064$].[29]

[26] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 24.88, p = .003. Huynh-Feldt correction was applied (ε = .85). Corrections were applied to interactions with STAI-T.
[27] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 175.72, p < .001. Greenhouse-Geisser correction was applied (ε = .40). Corrections were applied to interactions with STAI-T.
[28] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 24.55, p = .004. Huynh-Feldt correction was applied (ε = .87).
[29] Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, χ^2 (9) = 167.69, p < .001. Greenhouse-Geisser correction was applied (ε = .42).

4.4.2 Orienting Task

Separate ANCOVAs were conducted for accuracy and RT measures, testing the effects of within-subjects factors of validity (valid, invalid) and face emotion (fearful, neutral), and trait anxiety as the continuous predictor.

For accuracy, results revealed a marginally significant interaction between validity, emotion, and STAI-T [F (1, 46) = 3.69, p = .061, η_p^2 = .07]. There were no further main effects or interactions (all p's > .079). To clarify the marginally significant interaction, the validity effects (difference in accuracy between valid and invalid trials) for neutral and fearful distractor conditions were correlated with STAI-T scores. This revealed a significant positive correlation with validity effects for the neutral distractor condition [r = .30, p = .040], indicating that higher levels of trait anxiety were linked to greater validity effects for scenes with neutral distractors (Figure 4-2B). The correlation between validity effects for the fearful distractor condition and the STAI-T was not significant [r = -.079, p = .60].

To clarify the significant interaction further, and to better understand the overall lacking validity effect, I performed a median-split of the STAI-T scores (median = 38.5) in order to obtain high and low anxiety groups. A 2 × 2 repeated measures ANOVA was conduced separately for both groups, with validity and emotion as within-subjects factors. A significant validity × emotion interaction emerged for the high anxious group [F (1, 23) = 5.08, p = .034, η_p^2 = .18]. Post-hoc t tests revealed a significant validity effect for the neutral distractor condition [t (23) = 3.35, p = .003, d = 0.68, CI = (0.03, 0.15)]. That is, accuracy was significantly greater in valid compared to invalid trials [valid: 77.6%, 95% confidence interval, CI = (74.3%, 80.8%) invalid: 71.1%, CI = (67.0%, 75.2%)].

The validity effect of the fearful distractor condition was not significant [t (23) = 3.35, p = .59] (Figure 4-2C). Results from the low anxious group showed no significant main effects or interactions (all p's > .20).

To ascertain whether threatening distractors affected exclusively valid trials, i.e. memory cues, in the high anxious group, paired samples t tests were conducted to compare accuracy on valid and invalid trials for threatening and neutral distractor conditions. This revealed that the fearful face distractors, compared to neutral face distractors, impaired accuracy on only valid trials, [t (23) = 2.73, p = .012, d = 0.56, CI = (0.01, 0.08)], but not on invalid trials [t (23) = -0.15, p = .88].

An ANCOVA on RTs for correct trials revealed no significant main effects or interactions (all p's < .20).

As was done in Chapter 3 and given the high comorbidity between anxiety and both neuroticism and depression, ANCOVAs were also conducted using scores on the EPQN and the BDI to examine whether the set of results extends to measures of neuroticism and depression, respectively. The Shapiro-Wilk test revealed that both the EPQN and the BDI scores exhibited non-normal distributions (p < .001 for the BDI; p < .001 for the EPQN). Thus, log transformations were conducted on both sets of scores, which resulted in normal distributions, although at marginal significance (p = .069 for the BDI; p = .078 for the EPQN). Analyses for the BDI revealed a significant validity × emotion × BDI interaction [F (1, 46) = 9.35, p = .004, η_p^2 = .17]. As was done for post-hoc analyses with trait anxiety, the validity effects for neutral and fearful distractor conditions were computed and correlated with BDI scores. This revealed a significant positive correlation for the neutral distractor condition [r = .34, p = .038], suggesting that higher levels of depression were associated with higher validity effects when neutral

distractors were presented. The correlation with the fearful distractor condition was not significant (p = .14). Further, when conducting a median-split (median = 1.79), the high BDI group showed a significant interaction between validity and emotion [F (1, 23) = 8.43, p = .008, η_p^2 = .27]. Post-hoc t tests revealed a significant validity effect for the neutral distractor trials [t (23) = 3.88, p = .001, d = 0.79, CI = (0.04, 0.13)]. Results for the low BDI group revealed no significant main effects or interactions (all p's > .062). Results for the EPQN revealed a marginally significant interaction between validity, emotion, and the EPQN [F (1, 46) = 2.87, p = .097, η_p^2 = .59]. All other main effects and interactions were not significant (all p's > .15).

Finally, the degree to which results are also driven by state anxiety was assessed using a comparable ANCOVA. The Shapiro-Wilk test revealed a non-normal distribution of STAI-state scores (p < .001). A log transformation, however, did not normalise the distribution (p = .007). Thus a median split (median = 29.50) was conducted to obtain low and high state anxious groups and the Mann-Whitney U test was conducted on accuracy for validity × emotion conditions. Results showed a marginally significant difference between groups in accuracy for the valid fearful condition, with greater accuracy in the high state anxious group (U = 201, p = .072). There were no further significant differences in accuracy between high and low state anxiety groups (all p's > .190).

4.4.3 Memory Task

Memory data from one participant could not be collected due to technical problems. The mean distance, across participants, was 281.93 pixels (SD = 91.82). Participants' confidence ratings varied in accordance with the mean distance between their response and the key location so that they became less confident as their accuracy decreased (Figure 4-3B).

An ANCOVA was conducted to assess whether target validity and distractor emotion from the preceding Orienting Task affected subsequent explicit recall, indexed by mean distance, with within-subjects factors of validity (valid, invalid) and face emotion (fearful, neutral), and STAI-T as the continuous predictor. Results revealed no main effects or interactions (all p's > .23). These findings indicate that the previous validity of the key location and the distractor emotion did not influence subsequent explicit recall.

Recall of the faces was at chance level (50% accuracy). These results suggest that participants were unaware of the emotional valence of the distractor faces across trials. However, these results may also indicate that participants were simply not able to recall the emotional valence, making it difficult to ascertain unequivocally that they lacked awareness of distractor emotion in the preceding Orienting task. Given the brief presentation times of distractors and participant feedback suggesting an unawareness of the emotionality of faces, it seems plausible that distracting emotion did not achieve awareness.

4.4.4 Dot-Probe Task

The dot-probe task was analysed using an ANCOVA, with word valence as the within-subjects factor and STAI-T as the continuous predictor. Results revealed no significant main effects or interactions (all p's > .69), suggesting that older adults in the current study did not exhibit an attentional bias to threatening words.

As Fox and Knight (2005) found that induced anxiety predicted attentional biases to threat, independently of trait anxiety, in the dot-probe task, the extent to which state anxiety revealed threat biases was assessed. Since state anxiety scores were not normally distributed, even after a log transformation (as described above), a Mann-Whitney *U* test was conducted to

assess differences in RTs for threatening and neutral words between low and high state anxious groups. However, this also did not reveal any significant differences (all p's > .60).

Threatening	788.43 (± 21.63)
Neutral	785.89 (± 21.16)

Table 4-2: Results from the dot-probe task. Mean RTs for threatening and neutral words are shown with *SEM* in parentheses. There were no significant differences in RTs for threatening and neutral words.

4.4.5 Age Comparison

In order to obtain an estimate of age-related changes in threat biases and to account for overall slower RTs in older adults, I computed a normalised validity effect [(valid−invalid)/overall mean across trials], a normalised emotion effect [(neutral−fearful)/overall mean across trials], and separate validity effects for fearful and neutral conditions and separate emotion effects for valid and invalid conditions. Independent samples *t* tests were conducted to compare theses effects between the current older adult sample and the younger adult sample from Experiment 1 of Chapter 2. Comparisons were limited to the sample in Experiment 1, as the ISI duration was identical to that used in the current study.

Results revealed a marginally significant difference in the overall validity effect [t (78) = 1.86, p = .066, d = 0.44, CI = (-0.003, 0.10)], with greater validity effects in the young adults (M = 0.08 ± SEM = 0.02) compared to the older adults (M = 0.04 ± SEM = 0.02). Further *t* tests were conducted to compare anxious and non-anxious older and younger adults. Results revealed that low anxious young adults showed a significantly greater validity effect compared to low anxious

older adults [t (39) = 2.28, p = .028, d = 0.73, CI = (-0.008, 0.15)]. There were no significant differences between high anxious older adults and young anxious adults [t (37) = 0.29, p = .78]. There were no further significant differences between groups (all p's > .17).

To determine differences in initial learning of key locations, which may have contributed to the observed differences in validity effects, linear regression learning slopes of search times were computed. Results of the independent samples t test revealed a significant difference between old and young adults, across anxiety groups [t (78) = 2.16, p = .034, d = 0.62, CI = (-0.28, -0.01)], with young adults exhibiting significantly steeper learning slopes (M = -0.57 ± SEM = 0.04) compared to older adults (M = -0.42 ± SEM = 0.05). Additional t tests using accuracy on the Learning task showed no significant age differences (all p's > .31).

An independent samples t test was also conducted for explicit memory recall and revealed a significant difference in mean distance (between the actual and indicated key locations) between older and younger samples, across anxiety [t (77) = 3.73, p < .001, d = 0.87, CI = (34.63, 114.09)], with older adults showing a greater mean distance, i.e. poorer recall (M = 281.93 ± 13.39 pixels), compared to younger adults (M = 207.56 ±14.05 pixels). However, it is important to note that the key was larger for the older adults and thus the computed mean distance is inflated. When scaled to the actual key size, young adults exhibited a mean distance equivalent to approximately 4.22 keys, while the mean distance for older adults was approximately 4.6 keys, thus indicating minimal differences in recall. Therefore, it is difficult to conclusively ascertain differences in explicit memory between samples.

Although the young adult sample size was smaller than that of the older adults, Levene's Test for Equality of Variance was non-significant for all independent samples t tests.

4.5 Discussion

The current study investigated the impact of emotional distractors on memory-guided attentional orienting and modulations by trait anxiety in a sample of healthy older adults. In addition to investigating anxiety effects within the older adult participants, comparisons with results of Experiment 1 of Chapter 3 provide insight into modulations by age.

For the Learning task, contrary to predictions, results showed no effects of trait anxiety. These results contrast with evidenced anxiety-related learning deficits, resulting from difficulties in categorising incoming information (Yochim et al., 2013). Pietrzak et al. (2012) showed anxiety-related learning impairments using the Continuous Paired Associate Learning task (CPAL), which assesses visual learning and memory. As the CPAL task requires participants to learn the locations of non-emotional figures, it resembles the Learning task in the memory-guided orienting paradigm. The authors posited that impaired learning was attributable to anxiety-related deficits in executive functions, including shifting and inhibition. Similarly, Beaudreau & O'Hara (2009) demonstrated inhibitory deficits in anxious older adults using a non-emotional Stroop task. Instead, anxious participants in the current study exhibited no difficulty in inhibiting the salient distracting stimuli saturating the naturalistic scenes and therefore displayed comparable learning to their non-anxious counterparts. The divergent findings may stem from the specific task demands, which may have made anxiety-related measures insensitive. As participants were allotted two minutes to locate the key, the limited resulting variability in both accuracy and search times may have precluded the detection of modulations by anxiety. With a more restricted time window for learning, anxious participants may have exhibited poorer accuracy and greater distractibility by salient information, causing slower learning. Moreover, the CPAL task uses varying set sizes of to-be-learned stimuli, thus manipulating memory load. The consistent use of

only a single key target, coupled with the long duration of time to locate the target, may have rendered it difficult to detect anxiety differences in the current task. Further research is required to clarify differences in spatial learning as a function of trait anxiety.

However, learning slopes showed differences between age groups, with older adults exhibiting overall shallower learning, potentially reflecting age-related decrements in inhibitory difficulties (Tipper, 1991). Deficient inhibition consequently enables distracting information to gain access to attention, resulting in the interference of task execution (Hasher, Stoltzfus, Zacks, & Rypma, 1991). Thus, older adults may have been overly distracted by the abundance of information depicted within the naturalistic scenes, leading to slower learning of spatial-contextual associations.

Contrary to the Learning task, results of the Orienting task revealed modulations by trait anxiety. In particular, while older adults with low levels of anxiety and depression did not show a validity effect, those with high levels exhibited a validity effect exclusively for the neutral-distractor trials. The absent validity effect in the low anxious participants, across distractor emotion conditions, suggests that distracting information captured attention and interfered with overall task performance. These findings suggest that late adulthood is marked by an impaired ability in utilising memories to guide attention when distractors are concurrently presented with memory cues. As emotion regulation, which underpins the positivity bias, relies on sufficient cognitive resources, tasks that exhaust these resources cause a reduction in the bias. Knight et al. (2007) found that the enhanced emotion regulation typifying late adulthood was eliminated in divided attention tasks due to the depletion of cognitive resources. Thus, the presence of distractors may have encumbered processing such that the emergence of a positivity bias was hampered.

The lack of an interaction with emotion, i.e. an absence of additional task impairment by fearful face distractors, suggests that healthy older adults are not exclusively distracted by negatively charged information. While the non-anxious young adults were likewise unaffected by distractor emotion, they were able to effectively use memory cues, overriding disruption of distractors. Instead, the availability of multiples cues may have augmented task load in older adults, whose thresholds for cognitive load are lower, thereby enabling distractors to disrupt processing (Lavie, 2005). Similar to the Learning task, results in the Orienting task may be attributable to age-normative decline in the inhibition of task-irrelevant information (Hasher et al., 1991). Moreover, attentional control is similarly prone to decline, causing difficulties in selecting and sustaining attention to pertinent information (Milham et al., 2002). Taken together, age-related decline in inhibition and top-down control functions may have allowed the distractors to disrupt task performance.

However, rather than due to distractors, an alternative explanation for the observed task disruption is a possible inadequate formation or retention of memories in the previous Learning task. As binding, i.e. creating associations between items, has been shown to be impaired in older adults (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), the formation of memories may have been thwarted. Since no-distractor trials were not included, in order to restrict the quantity of trials and thus curb experimental duration, I cannot unequivocally ascertain the underlying cause of the lacking validity effect. However, as the study by Salvato, Patai, and Nobre (2016) revealed validity effects using the memory-guided orienting paradigm, it is reasonable to assume that the addition of the distractors in the current study caused the differing results. To clearly ascertain whether the incorporation of distractors interfered with the employment of memories in directing attention, future studies should include no-distractor trials.

In contrast, older adults with high levels of anxiety and depression showed a validity effect, yet exclusively on trials with neutral face distractors. The contrasting absent validity effect in the fearful distractor condition reveals the potency of threat in disrupting the recruitment of memory cues. These results correspond to anxiety-related threat disruption evidenced in both young adults (Bar-Haim et al., 2007) and older adults (Price et al., 2012), and suggest that the positivity bias does not safeguard against the anxiety-related attentional pull of threatening stimuli. Importantly, however, while the threat disruption impeded the recruitment of memories, it did not cause overall task disruption as shown by the lacking emotion effects on invalid trails. That is, fearful distractors, compared to neutral distractors, did not exacerbate the inefficient search required on invalid trials. These findings contrast with those in the high anxious young adults, who showed task disruption by fearful distractors on both valid and invalid trials. The distinguishing lack of overall disruption in anxious older adults may be attributable to the greater cognitive effort required on invalid trials, for which memory-guided attention is supplanted by active search. The increase in cognitive demand may have been especially disruptive in older adults, precluding differential emotion effects, and thereby resulting in the observed discrepancy in findings between age groups.

Contrary to the adverse effects of fearful face distractors on memory-guided orienting, the preserved validity effect for the neutral face distractor condition suggests that anxious older adults were able to dismiss non-emotional distracting information. Given the overall distractor-induced disruption in low anxious participants, the validity effect in high anxious participants was unexpected. The intact use of memories in the face of neutral distractors may stem from compensatory strategies employed by anxious participants. The adoption of such strategies is delineated by the Processing Efficiency Theory (Calvo & Eysenck, 1992), which contends that a

central regulatory control system uses performance feedback signals to regulate processing resources. The heightened worry about task performance plaguing anxious individuals leads the control system to reserve additional resources and increase expenditure of these resources as a means of mitigating worry. Ansari & Derakshan (2011) demonstrated the increase in task effort to offset feelings of worry using an anti-saccade task and revealed greater contingent negative variation (CNV) activity, indexing enhanced cognitive effort, in anxious young adults. The employment of strategies has also been evidenced in anxious older adults. As described earlier, Lee and Knight (2009) showed that trait anxious older adults exhibited an automatic avoidance of negative words in the dot-probe task, postulated to stem from a lifetime of practice in avoiding negative information in an effort to abate worry. Applied to the current results, anxious participants may have employed compensatory strategies that increased processing resources and thereby facilitated effective target detection on trials with benign distractors. Yet, while strategies motivated by worry may have allowed anxious participants to discount distracting neutral information, fearful face distractors may have been excessively taxing on processing so as to prevent any benefit of additional resources.

Alternatively, due to greater levels of state anxiety and resulting increases in arousal, anxious older adults may potentially have experienced an overall heightened arousal-induced vigilance. The Yerkes-Dodson Law (Yerkes & Dodson, 1908) posits a curvilinear relationship between arousal level and task difficulty, such that moderate arousal levels are optimal for bolstering task performance on moderate levels of task difficulty. With increasing task difficulty, however, lower levels of arousal are beneficial for ensuring task success. Anxious participants in the current study may have therefore experienced optimal levels of state anxiety so as to allow proficient use of memories for key detection. While state anxiety was significantly higher in the

high anxious/depressed participants, compared to the low anxious group,[30] their mean level of state anxiety did not fall within clinical levels and instead corresponded to average levels previously reported in healthy older adults (Kvaal, Ulstein, Nordhus, & Engedal, 2005). These moderate levels of state anxiety, and the corresponding arousal, may therefore have created favourable conditions for enhanced performance. The performance enhancement exclusively on valid trials suggests that heightened arousal may have facilitated the recruitment of memories but did not aid detection on the inefficient search on invalid trials, potentially due to a high degree of difficulty. Such arousal-induced facilitation of memory recruitment exclusively occurred in the neutral face distractor condition, suggesting that the fearful face distractors may have been excessively disruptive so as to prevent comparable arousal-induced facilitation. Taken together, it remains unclear whether the validity effect on neutral face distractor trials is underlain by compensatory mechanisms or by an arousal-induced vigilance and the speculative nature of both alternatives warrants further research.

In contrast to the Orienting task, the Memory task revealed no modulations by trait anxiety. That is, anxious older adults did not exhibit poorer memory recall. These findings contrast with evidence revealing both clinical and high trait anxiety as risk factors for decline in memory function (Pietrzak et al., 2012; Sinoff & Werner, 2003). However, explicit memory was overall poor in the current sample, therefore rendering it difficult to detect potential differences as a function of anxiety. The poor accuracy[31] corresponds to the lacking validity effect in the preceding Orienting task in the low anxious participants. The extent to which aging affects these

[30] State anxiety, as measured by the STAI-state, was significantly greater in high trait anxious participants and high depressed participants: [for STAI-T: t (32.37) = -5.08, $p < .001$, d = 1.47, CI = (-18.63, -7.99); for depression: t (35.49) = -3.90, $p < .001$, d = 1.13, CI = (-16.85, -5.31)].

[31] I additionally computed an index of accuracy in percentage, using a circle with a radius of 75 pixels around the actual key location to define accurate responses. Using this index, older adults showed a mean accuracy of 41.10%.

explicit versus implicit memory systems remains inconclusive, with some studies having found impaired explicit memory function but spared implicit memory (Fleischman, Wilson, Gabrieli, Bienias, & Bennett, 2004; Salvato et al., 2016) and others having detected impairments in both systems, albeit greater for explicit memory (Ward, Berry, & Shanks, 2013). As discussed earlier, it cannot be unambiguously established whether the absent validity effect is attributable to impaired implicit memories or instead to an inability in extracting intact implicit memories due to concurrent distractors. Although findings can therefore not discern the effects of ageing on implicit memories, they illustrate the importance of taking into account the emotional nature of stimuli when assessing memory function. Moreover, the preserved recruitment of implicit memories on neutral distractor trials in anxious older adults highlights the importance of considering inter-individual differences.

Compared to young adults, explicit memory was poorer in older adults, corresponding to findings of age-normative decline in memory function (Cabeza, Nyberg, & Park, 2009). Memory decrements in older adults have been linked to decline in the neural structures within the medial temporal lobes, particularly the hippocampus, that underpin long-term memories of contextual information and support the consolidation of learned information into memory storage (Davachi, Mitchell, & Wagner, 2003; Giovanello, Kensinger, Wong, & Schacter, 2010). Moreover, previous studies have demonstrated age-related impairments in binding associations between various items, which results in poor memory (Naveh-Benjamin et al., 2003). The poorer memory recall exhibited by older adults in the current study suggest that the greater acquisition of information due to inhibitory deficits, that may explain the slowed learning in older adults, did not confer memory benefits. These findings corroborate evidence that older adults possess a combined deficit in inhibition and binding (Ryan, Leung, Turk-Browne, & Hasher, 2007).

However, as noted in the Results section, given the different key sizes used for younger and older adults, it is difficult to ascertain the extent to which differences in mean distance reflects actual differences in explicit recall. Thus, the current interpretation of poorer memory must be viewed with caution.

Finally, the lack of results on the dot-probe task, when using trait anxiety as a continuous predictor and state anxiety groups in a non-parametric test, differs from previous studies (Fox & Knight, 2005; Lee & Knight, 2009). The discrepancy in results illustrates the need to consult other approaches. Indeed, previous studies have shown that attentional biases in older adults may not be reliably detected using the dot-probe task, as it is dependent on processing speed that is marked by greater inter-individual variability in older adults (Price, Eldreth, & Mohlman, 2011).

Current results also pave the way for further research. In particular, eye tracking would be a useful addition in order to clarify whether the presence of distractors in the Orienting task caused the impedance of memory-guided orienting in the non-anxious participants. Additionally, it would be interesting to explore how varying stimuli durations would affect attentional patterns and potentially reveal a positivity bias. Using 1000-ms stimuli presentation times, Demeyer and De Raedt (2013) found that non-anxious older adults avoided negative information. Similarly, Tomaszczyk and Fernandes (2014) used 1000-ms presentations to reveal that while younger adults exhibited a bias to threat in attentional orienting, older adults oriented their attention to positive information. Thus, the absent positivity bias in non-anxious older adults in the current study may be attributable to the brief stimuli durations of 100 ms. Increasing the duration of the distracting faces in the current study may allow for deliberate avoidance strategies to be executed, thereby enabling a positivity bias to manifest, i.e. a validity effect for fearful face distractors. Similarly, Lee and Knight (2009) evidenced avoidance of negative stimuli at longer durations in

anxious older adults. The absent validity effect in anxious participants due to the fearful faces may be attenuated or eliminated if avoidance mechanisms are enabled with longer presentation times. Further, while positive face distractors were not included in order to limit task duration, a follow-up study should supplant the neutral faces with happy faces to better assess a positivity bias and corresponding age-related changes. Finally, future research may also investigate the neural correlates of the diminished memory recruitment. Summerfield et al (2006) showed hippocampal activation uniquely during memory-guided orienting, differentiating it from activation during orienting using visual cues. Accordingly, neuroimaging would complement the current behavioural results by examining whether hippocampal recruitment is diminished in older adults, providing support for the deficient use of memoires. Moreover, an examination of changes in activity in regions implicated in inhibitory control, including the superior frontal gyri, the intraparietal sulci, and the anterior cingulate cortex (ACC), would clarify the role of distractors in causing task disruption in low anxious participants. Finally, the interference by fearful face distractors in specifically anxious older adults can be further delineated by examining activity in the rostral ACC, which is involved in emotion regulation in response to threatening information and has been shown to elicit diminished activity in anxious individuals, reflecting poorer emotion regulation to threat (Bishop, Duncan, Brett, & Lawrence, 2004).

The current results contribute to the limited extant research regarding attentional biases to threatening information in anxious older adults. The memory-guided orienting paradigm provides a novel approach to understanding how salient distracting emotional information competes with task-relevant endogenous memory cues. Moreover, the learning and explicit memory components enable an exhaustive investigation of anxiety-related modulations in late adulthood. Finally, comparisons with the young adult sample of my previous study revealed age-normative changes

in learning and memory performance. Taken together, findings underscore the importance of tailoring the investigation of attentional patterns and modulations by trait anxiety to the unique cognitive profiles of older adults, rather than generalising findings from young adults.

5 Effects of Attentional Capture by Threat on the Rapid Deployment of Spatial Attention

The degree to which attention can be rapidly redirected between successive stimuli is dictated by the joint contribution of bottom-up and top-down capture. As threatening information is granted privileged access to attentional resources, due to its biological relevance, the current study explored how threatening stimuli affect processing of temporally proximate benign information. Using the N2pc as a marker of spatial selection of salient information, the study provides a temporally precise account of attentional allocation to both task-relevant and task-irrelevant threat and to subsequent stimuli. The study developed a novel task that presented two pairs of faces in rapid succession, with each pair containing one target and one distractor. Participants were required to indicate whether the two successive targets, marked by colour, were of the same sex. Emotion was only manipulated in the first pair, with the threatening face serving as either the target or the distractor. The study was intended as an initial assessment of the efficacy of the task, and as a basis for further research, and therefore trait anxiety was not included. Results showed that neutral face targets paired with fearful face distractors elicited diminished N2pc amplitudes, indexing reduced attentional selection. These results demonstrate attentional capture by threatening distractors, which in turn detracted resources for target processing. Instead, amplitudes to fearful face targets were not enhanced, suggesting that top-down task demands rendered all target stimuli equally salient. However, contrary to predictions, processing of subsequent neutral face targets was unaffected by early threat. These findings may be due to the use of sufficiently long ISIs that enabled recovery from threat. Moreover, the inclusion of anxiety may reveal greater modulations by emotion.

5.1 Introduction

Our visual environment contains an abundance of dynamic stimuli, rendering it necessary to process temporally overlapping information. Studies have shown that our attention can be readily shifted between stimuli occurring in rapid succession, even when these stimuli are presented in different locations within the visual field (Eimer & Grubert, 2014) and when stimuli selection is determined by multiple features, precluding the use of a single attentional template (Grubert & Eimer, 2015). The ease with which attention can be disengaged from a currently processed

stimulus and reoriented to a subsequent stimulus is in part dictated by the relative salience of the stimuli (Siebold & Donk, 2014; Vuilleumier, 2005).

The aim of the current study was to develop a task to investigate the degree to which emotional content of stimuli influences the timing of attention selection across successive targets. The study measured the N2pc, a well-established event-related potential (ERP) marker of covert spatial selection of a salient or relevant stimulus within an array, to investigate the timing of target selection and how such selection is potentially modulated by task-relevant and task-irrelevant threat. This investigation may be of particular relevance for understanding how the interface between attention and emotional material may adversely influence attention-related functions in mood disorders, and thus compromise adaptive behaviour. Although trait anxiety was not considered, the current study is intended as a foundation for further research.

Studies of selective attention have underscored the role of both bottom-up capture by physically salient items (Theeuwes, 1992) and top-down, contingent capture by task-relevant stimuli independent of low-level features (Folk, Remington, & Johnston, 1992). While different theoretical perspectives posit differential weighting between these inputs, there remains agreement that both sources operate in tandem to influence processing (Desimone & Duncan, 1995). A study by Seiss, Kiss, and Eimer (2009) showed that the N2pc was elicited by pop-out coloured stimuli presented in uncued and task-irrelevant locations, exhibiting amplitudes and onset latencies that were comparable to those elicited by task-relevant stimuli appearing in attended locations. These findings therefore support a bottom-up salience-driven hypothesis. However, Brignani, Lepsien, and Nobre (2010) instead demonstrated that the N2pc elicited by stimuli that shared target-defining features, but with no additional low-level distinctive features, at uncued and task-irrelevant locations was equivalent to that elicited by the spatially attended

target stimuli. Thus, low-level physical salience is not required for robust attentional capture. Taken together, these studies provide support for both bottom-up and top-down factors contributing to attentional capture through salience and relevance, respectively.

The emotionality of stimuli is an important additional source of attentional bias and can influence the relative input of bottom-up and top-down signals in driving attention (Mohanty & Sussman, 2013; Vuilleumier & Driver, 2007). Negatively charged stimuli have been proposed to be intrinsically salient on account of their biological relevance (Bannerman, Milders, & Sahraie, 2010; Öhman et al., 2001) and therefore capture attention in an automatic, bottom-up manner. Such involuntary capture by threat is shown in a study by Hodsoll, Viding, and Lavie (2011) that revealed capture by task-irrelevant fearful faces using a task requiring discrimination of the sex of emotional faces. However, top-down demands also influence the strength of the effects that emotion exerts on attention (Pessoa & Adolphs, 2010; Sussman, Jin, & Mohanty, 2016). A study by Eimer and Kiss (2007) presented task-irrelevant fearful and neutral singleton faces within arrays of distracting faces and required participants to detect luminance changes of the fixation cross. On trials without luminance changes, irrelevant fearful faces elicited an N2pc. However, on trials in which luminance changes were introduced, N2pc amplitudes to distracting fearful faces were reduced. These results show that task-irrelevant threat can modulate the distribution of spatial attention but that top-down task demands interact with the automatic capture of threat. Similarly, a study by Glickman and Lamy (2018) showed that the ability of distracting emotional faces to capture attention in a bottom-up fashion is contingent on task demands. In particular, distracting faces with unique expressions of fear were disruptive to task performance when face targets were singletons on a different dimension (orientation). However, when targets were not singletons and thus a singleton-detection mode was not adopted, distracting emotional faces

showed no attentional capture. Taken together, the extent to which threat captures attentional resources reflects the broader debate regarding the bottom-up versus top-down contributions to salience-driven capture.

Studies devoted to attention have often employed visual search tasks to explore how stimuli compete in space when presented concurrently. However, engagement with stimuli not only affects the degree to which competing spatially proximate stimuli are processed but also has important consequences on the attentional selection of temporally proximate stimuli. The rapid serial visual presentation (RSVP) paradigm has been used to study the degree to which emotionally salient information attenuates, or entirely impedes, processing of subsequent targets. Within RSVP streams, a phenomenon labelled the attentional blink (AB) occurs when two target stimuli appear in rapid succession. Detection of the first target results in diminished processing of the second target, which can go altogether undetected. Using single letters as stimuli, Raymond, Shapiro, and Arnell (1992) showed that an AB occurred 180–270 ms post-target onset. As an explanation for these results, the authors proposed a model positing an attentional 'gate' that is opened when target-defining features are detected and is shut once targets are identified. An incoming, novel item during this interval will demand processing, alongside processing of the target, and will thus encumber target identification due to the addition of features requiring processing. The burden caused by distracting features consequently triggers a suppression response in order to restrict further incoming information that might exacerbate the target identification process, resulting in a shutting and locking of the attentional gate. Subsequent targets appearing during this shut-and-locked time window, akin to an eye blink, are therefore not processed. Subsequently, Shapiro and Raymond (1994) proposed an interference theory, which explains that stimuli in the RSVP stream enter into visual short-term memory (VSTM), where

they are assigned relative weightings, depending on the strength of the match between perceptual features of the stimuli and corresponding internal selection templates. It follows that an initial target stimulus receives a strong weighting, as it closely matches the template of target-defining features. The second target similarly obtains weighting due to a template match. However, distracting items occurring within the interval between targets may also gain entry to VSTM and thereby consume processing resources. At short intervals between targets, resources remain depleted, consequently weakening the weighting of the second target in VSTM. The diminished weighting causes incorrect stimulus selection that is behaviourally evidenced as an AB. Instead, at longer intervals, the weighting obtained by the distractor will have degraded with time, with resources resultantly replenished (Raymond, Shapiro, & Arnell, 1995). Chun and Potter (1995) build on these previous accounts and put forth the two-stage model, which attributes AB to limited attentional resources. This model posits that visual information must proceed through two sequential processing stages, with the first devoted to the rapid detection of stimuli and the generation of a semantic and perceptual representation of information and the second step involving the consolidation of these representations into working memory. While the first processing stage has a large processing capacity, the subsequent stage is more limited. Thus, if the interval between the targets is brief (approximately 200–400 ms), it follows that the second target cannot obtain attentional resources, as the first target has not completed the second capacity-limited processing step, creating a backlog of to-be-processed stimuli. The two-stage model therefore places this attentional bottleneck at the late processing stages of working memory consolidation and argues that early perceptual processing remains unaffected by serially presented stimuli (Chun & Potter, 1995; Kennedy, Rawding, Most, & Hoffman, 2014).

Importantly, the emotional valence of stimuli modulates the degree of AB. Given the privileged access to attentional processing granted to threatening information, studies have shown a reduction in AB if the second target is endowed with emotional salience (Maratos, Mogg, & Bradley, 2008). That is, the limited-capacity bottleneck seems to allow flexible entry for emotional material. In addition, initial emotional targets have been shown to adversely affect processing of a subsequent neutral target to a greater extent, compared to non-emotional early targets (Mathewson, Arnell, & Mansfield, 2008). Emotion-induced blindness (EIB) is a similar phenomenon to AB and entails a dampened awareness to stimuli presented shortly after a task-irrelevant emotional stimulus (Kennedy et al., 2014; MacLeod, Stewart, Newman, & Arnell, 2017; Most et al., 2005). EIB tasks use a single target that is presented within a series of threatening, neutral, or non-emotional distractors. With short intervals between targets and negative distractors, the former receives diminished processing. Most et al. (2005) showed that the presentation of a single threatening image in a RSVP stream of landscape and architectural images reduced accuracy for a target. This EIB was contingent on the ISI, occurring at 200 ms and then waning at 800 ms, corroborating the notion of sequential capacity-limited processing stages. However, in contrast to evidence of EIB, Taylor and Whalen (2014) found that the presentation of fearful faces as initial targets *enhanced* detection of subsequent targets. That is, if initial targets depicted fearful expressions, detection of a peripheral non-emotional subsequent target was facilitated, relative to conditions with neutral and angry faces as initial targets. The discrepancy in results, i.e. facilitated versus impaired detection of a second target following threat, may stem from the different types of stimuli used. While many studies used negatively charged scenes (Kennedy et al., 2014; Most et al., 2005) or angry faces (de Jong, Koster, van Wees, & Martens, 2010; Maratos et al., 2008), the fearful faces used in the study by Taylor and Whalen (2014) were postulated to diffuse attention to the greater context in response to a

threatening stimulus. That is, the source ambiguity inherent to fearful faces causes attention to be broadened, in an attempt to identify the source of threat (Whalen, 1998), thereby boosting processing of subsequent stimuli. Instead, angry faces and negative scenes have a clearer source of threat and are therefore comparatively less ambiguous, which may instead lead to narrowed attention to the depicted source.

Investigations regarding the degree to which threatening stimuli affect processing of subsequent information have yielded differing results, partly as a function of the methodologies employed. The current study investigated whether attentional selection of fearful faces, serving as either targets or distractors, occurs more rapidly and involves more extensive processing, compared to neutral stimuli. To provide a sensitive measure of such selection, the N2pc component was measured to track the time course of attentional allocation to an initial threatening target or distractor, and to a successive neutral target. The precise temporal information afforded by electroencephalography (EEG) renders it a useful method for understanding the time course of attentional deployment to threatening information. In particular, ERPs provide the requisite high temporal resolution to assess rapid attentional allocation. The N2pc is an enhanced negative voltage deflection that originates within the ventral occipito-temporal cortex (Hopf, 2004; Hopf et al., 2000) and the posterior parietal lobe (Fuggetta, 2006). An early parietal source and a subsequent occipito-temporal source reflect an initial attentional shift executed by parietal areas followed by attentional focus achieved by occipital and temporal cortices (Hopf et al., 2000). The N2pc is thus elicited at posterior electrode sites and appears contralateral to an attended item approximately 200–350 ms after the onset of the stimulus (Kiss, Van Velzen, & Eimer, 2008; Luck & Hillyard, 1994). The component is interpreted as an index of attentional selection to salient or target stimuli (Brignani et al., 2010; Kuo, Rao, Lepsien, &

Nobre, 2009; Seiss et al., 2009).[32] The utility of ERPs in supplementing behavioural indices of differential attentional allocation to threatening, compared to neutral, information, i.e. attentional biases, is highlighted by a direct comparison of biases measured using the N2pc versus RTs. Using a dot-probe task, Reutter, Hewig, Wieser, and Osinsky (2017) demonstrated a clear discrepancy in neural and behavioural indices, as attentional biases measured using RTs yielded poor internal consistency and showed no correlation with anxiety, while biases indexed by the N2pc exhibited strong internal consistency and significant correlations with anxiety. Moreover, anxiety also correlated with both the mean amplitude and peak latency of the N2pc in response to angry faces. These findings have been corroborated by studies similarly demonstrating N2pc components elicited without corresponding behavioural modulations (Fenker et al., 2010; Ikeda et al., 2013; Kappenman, MacNamara, & Proudfit, 2013) and therefore highlight the sensitivity of EEG recordings as a purer measure of early attentional biases that behavioural indices may not as readily tap into. Previous studies have used the N2pc to measure differential attentional selection to emotional material, showing more pronounced N2pc components, indexed by earlier onset latencies and heightened amplitudes, in response to threatening, compared to neutral, targets (Eimer & Kiss, 2007; Feldmann-Wüstefeld, Schmidt-Daffy, & Schubö, 2011). Using a RSVP paradigm incorporating emotional distractors, Kennedy et al. (2014) found a larger N2 amplitude to negative, compared to neutral, distractors (given its centre in posterior electrodes, the authors surmised that the component specifically reflected the N2pc). Correspondingly,

[32] Debate remains regarding the precise underlying mechanisms being targeted, in particular whether the N2pc provides an index of the suppression of unattended information or instead the selection of attended information (Eimer, 1996; McDonald, Green, Jannati, & Di Lollo, 2013; Sawaki & Luck, 2011). For the purpose of this chapter, the N2pc was interpreted as reflecting attentional selection of salient information.

emotional distractors elicited a heightened P3b, which reflects consolidation into working memory,[33] evidencing the privileged access of emotional information to memory.

The current task was based on the task developed by Eimer and Grubert (2014) in which two pairs of stimuli were presented in rapid succession and participants were asked to indicate whether two targets, predefined by colour, belonged to the same alphanumerical category. The primary manipulation was the locations of the successive targets, which were either in the same or opposite hemifield relative to one another. As the N2pc is elicited contralateral to the attended stimulus, the appearance of a second target located in the opposite hemifield to the first target should cause a reversal in N2pc polarity. Using this task, Eimer and Grubert (2014) evidenced such polarity reversal, thereby showing how latencies of successive N2pc components can be used to infer the timing of attentional shifts between successive targets. The current study adapted this task to include emotional faces. While the use of alphanumerical characters provides an initial account of successful reorienting of attention, the emotionality of stimuli may modulate the degree of capture and thereby reorienting. The adapted task presented two pairs of faces in rapid succession, with each pair containing a target and a distractor. Participants were required to indicate whether the two successive targets were of the same sex. Emotion was manipulated in

[33] The significance of the P3b remains unclear, with varying findings across studies. The component stems from the temporal-parietal region and is thus posited to relate to attention and memory functions (Polich, 2007). Studies have shown that it is elicited by novel stimuli and is sensitive to probability estimates. Longer latencies (Falkenstein, Hohnsbein, & Hoormann, 1994), as a result of increasing cognitive load in tasks, indicate that the component reflects the evaluation of task-relevant stimuli. This evaluation of novel information has been taken to suggest that the ERP reflects 'context updating', i.e. an updating of extant schemata when deviations from expectations occur (Donchin & Coles, 1988). The P3b has also been delineated via an inhibition hypothesis, which explains that the broader P300 component reflects inhibition of irrelevant information in order to facilitate communication between the frontal and temporal-parietal areas, indexed by P3a and P3b activity, respectively, thereby enhancing memory processing (Polich, 2007). These are only a limited set of examples regarding the proposed nature of the P3b. Nonetheless, the P3b is commonly interpreted as reflecting working memory access and consolidation, as was done in the study by Kennedy et al. (2014) to reveal the prioritised access of emotional information into working memory. A study administering cognitive training in a sample of elderly participants showed working memory benefits mirrored by increased amplitudes of the P3b, thus further suggesting the component's reflection of working memory processes (Gajewski & Falkenstein, 2018).

only the first display, which contained a fearful face that was either the target or the distractor, paired with a neutral face, or two neutral faces as the baseline condition. This manipulation enabled an assessment of the extent to which (1) task-relevant threat affects attentional reorienting to subsequent targets, and (2) task-irrelevant threat affects attentional allocation to the concurrent target and reorienting of attention to successive targets. The use of ERPs in the current study provides a robust approach to understanding attentional biases, as they are time-locked to the appearance of the face arrays and thereby circumvent the noise that often marks behavioural indices. Using this precise index of attentional processing provides a clear understanding of the chronometry of threat distraction and its consequences on processing temporally proximate stimuli.

In line with an inherent biological attentional capture by threat (Kennedy et al., 2014; Mogg & Bradley, 1999; Öhman et al., 2001), I predicted that fearful targets would automatically capture attention, evidenced by quicker attentional selection (earlier N2pc onset latencies) and deeper processing (greater N2pc amplitudes), relative to the neutral baseline condition. Such capture would subsequently cause delayed latencies and reduced amplitudes of the N2pc to the second target, with the reduction proportional to the increase in amplitude to the first target. Further, I predicted that fearful face distractors would automatically capture attention by virtue of the salient emotion but that top-down task demands would dampen the degree of capture. This prediction would be reflected by reduced N2pc amplitudes to the concomitant neutral target, compared to the neutral baseline condition. Moreover, fearful face distractors would also delay and attenuate the N2pc to the second target, relative to the neutral baseline condition. It should be noted, however, that a previous study using a similar task of sex discrimination of emotional faces did not evidence impaired processing of targets appearing after initial threatening targets,

indexed by an absent AB, which was interpreted to stem from attention being diverted away from the emotionality of the faces due to the secondary task (Stein, Zwickel, Ritter, Kitzmantel, & Schneider, 2009). Thus, while the current task aimed to provide a realistic account of threat processing, in which threat is not explicitly emphasised via task demands, the methodology may inadvertently result in diminished processing of the fearful expressions and thus attenuate the potency of negative emotionality. However, other studies using emotional stimuli as initial targets provided evidence of AB, and attentional capture, even when the emotional quality was not emphasised by task instructions (Hodsoll et al., 2011; Mathewson et al., 2008).

The use of two ISIs allowed for an assessment of the speed at which attention can be reoriented from the first to the second target. As described earlier, if stimuli appear in close temporal proximity, the second stimulus will not gain ready access to attentional processing. Thus, if fearful faces affect the timing of attentional shift dynamics, the longer ISI would be sufficient to enable the system to recover from any encumbered shifts. I therefore predicted that capture by fearful faces, both task-relevant and task-irrelevant, would be particularly disruptive to processing of the second target in the case of a strained bottleneck at the 100-ms ISI but would show relatively attenuated disruption at the 300-ms ISI.

5.2 Methods

5.2.1 Participants

Thirty-four participants (16 females) were recruited through an online participant database. However, prior to any EEG analysis, thirteen participants were removed due to excessive eye movements, and an additional two were removed due to poor accuracy on the behavioural task

(below 50%). Thus, analyses were conducted on 19 participants, aged 18 to 35 years (mean age = 25.13, *SD* = 5.0; 13 females). The large number of participants who had to be excluded reflects the difficulty in performing the required discriminations of complex peripheral stimuli with peripheral vision while maintaining central fixation. All participants were right-handed, had normal or corrected vision, had no history of neurological or psychiatric illness, and were fluent in English. Participants gave their written informed consent and were compensated £15/hour for their participation. The study was approved by the Central University Research Ethics Committee of the University of Oxford (MSD-IDREC- R49068/RE001).

5.2.2 Procedure

Participants who met eligibility criteria were invited to attend a single experimental session at the Oxford Centre for Human Brain Activity at the University of Oxford. After providing consent, participants completed the STAI-trait (STAI-T; Spielberger, 1983). Although the study was intended to serve as a foundation for future research, I nonetheless collected anxiety data in order to potentially incorporate it into preliminary analyses. However, given the small final sample size and the inadequate spread of STAI-T scores of the remaining participants,[34] anxiety was not considered in the analyses.

After the completion of questionnaires, the EEG was set up, which took approximately 1 hour. After the EEG set-up was completed, participants were provided written task instructions and any outstanding questions were clarified. Participants thereafter completed 12 blocks of the

[34] Only six participants obtained scores above the 40 cut-off, which I previously used in other studies to distinguish between low and high anxious participants.

task, each containing 96 trials, in a dimly lit, shielded testing booth. The study took approximately 3 hours in total, including the EEG set-up time and breaks between blocks.

5.2.3 Stimuli and Apparatus

Consistent with my previous studies, stimuli were taken, with permission, from the Amsterdam Dynamic Facial Expressions Set (van der Schalk et al., 2011), the Radboud Faces Database (Langner et al., 2010), and the MacArthur Network Face Stimuli Set (Tottenham et al., 2009). A standardised oval was used to crop the faces to ensure that the faces were of a standard size across trials. The oval was placed so as to include only the eyes, nose and mouth, part of the chin, and the top of the hairline. Faces were presented on a black background and subtended 3.1° × 2.7° of the visual angle at a viewing distance of approximately 100 cm.

In order to use faces that enabled easy identification of sex, a pilot study was conducted in which 84 faces were presented on a touchscreen computer (Dell OptiPlex 9030 All-in-One) and a subset of 10 new participants were instructed to rate the extent to which each face resembled a male or a female. Ratings were recorded using a sliding scale on the touchscreen, ranging from 'very male' to 'very female'. For each pilot participant, the mean of the rating responses was calculated separately for the female and male face sets. Faces with ratings falling above this mean were defined as explicitly male or female. Thus, ratings were weighted against each participant's individual mean, to account for any response biases. Faces that were rated as explicitly male or female for at least 8/10 participants were included in the final set. This resulted in 45 faces, 15 female and 30 male. However, in order to have even numbers of each sex in the final set, 15 male faces with the highest ratings were selected for the final set. The final set included 30 out of the original 84 faces, i.e. 15 female and 15 male.

In the experimental task, two arrays, containing two faces each, were displayed in succession (Figure 5-1). For any given trial, the four faces were of different actors. In each array, one face appeared on the left and one on the right at an eccentricity of 5.3° from central fixation. Faces were either tinted blue or red to indicate the target colour. Thus, each display contained one blue face paired with one red face. Participants were told to attend to either the blue or red faces for the duration of the study and were asked to indicate whether the first target (T1) and second target (T2) were of the same sex. Half of the trials presented faces of the same sex, with half of these trials showing a female pair and the remaining half showing a male pair. For those trials presenting targets of different sex, the male face appeared as the first target on half of the trials.

Stimuli were presented on a 1920 × 1080-pixel Dell colour monitor. Each display of stimuli pairs was presented for 200 ms and separated by an ISI of either 100 ms or 300 ms. The first display (Display 1) contained either a fearful face target and a neutral face distractor, a neutral face target and a fearful face distractor, or a neutral face target and a neutral face distractor. The two ISI durations were blocked and the order of the blocks was counterbalanced across participants. Trials were separated by an ITI of 1000 ms following the offset of the second display (Display 2) or after a response was made.

Responses were made within the ITI and any responses made after the ITI were excluded from analyses. Participants were instructed to respond quickly but with an emphasis on accuracy. They were not provided with feedback. To ensure that participants correctly classified faces, they were shown all the faces, in the target colour, at the start of the task. The sex of each face was indicated in writing below the face and participants viewed faces at their own pace. Each face was presented twice, depicting a fearful and neutral expression sequentially in a randomised order.

The experiment consisted of 12 blocks of 96 trials each. Six blocks used a 100-ms ISI and the remaining 6 used a 300-ms ISI. Half the participants were assigned to the blue condition and the other half to the red condition. The colour assignment remained balanced for the final 19 participants, with 10 participants having been assigned to the red condition and 9 participants having been assigned to the blue condition. There were 192 trials for each combination of emotion (fearful target, fearful distractor, and neutral/neutral) and hemifield relation of the two targets (same hemifield, opposite hemifield).

5.2.4 EEG Recording

The continuous EEG was recorded from 61 Ag/AgCl scalp electrodes, using a Compumedics Neuroscan EEG system with Synamps digital amplifiers (Neuroscan, El Paso, TX). Electrodes were positioned in accordance with the International 10-10 System (AEEGS, 1991). Other electrodes were used as the ground and for recording EOG. The horizontal EOG was recorded with one electrode on the side of each eye. Vertical EOG was recorded with electrodes under and above the left eye. All electrode impedances were kept below 5 Ωk. The right mastoid was used as the active reference, and recordings from the left mastoid were used to compute an averaged reference off-line. EEG activity was recorded and digitised at a sampling rate of 1000 Hz. All additional processing was done offline.

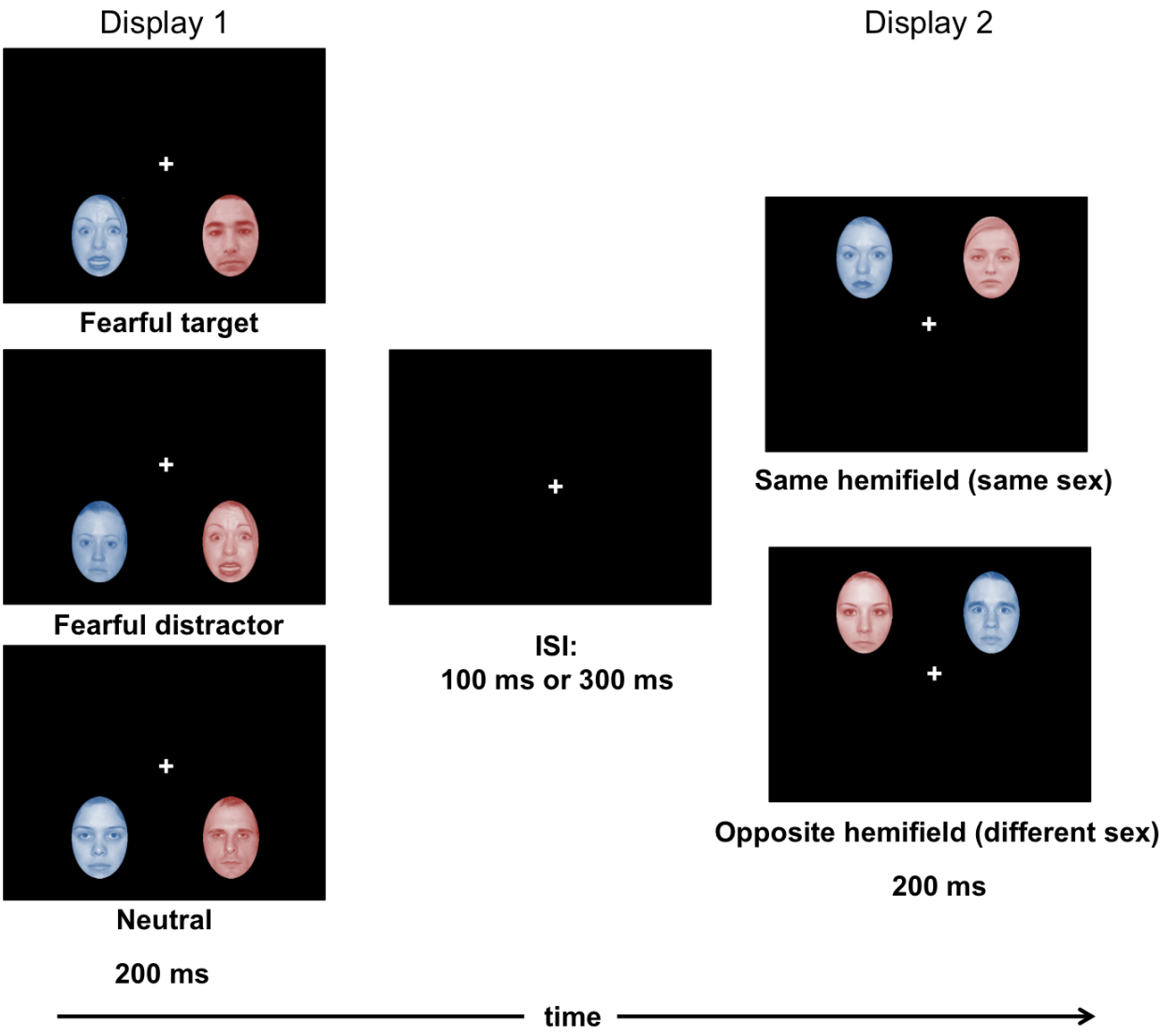


Figure 5-1: Schematic illustration of the experimental task, using the example of a blue target condition. Participants were assigned to either the blue or red target condition. There were three emotion conditions for Display 1, followed by an ISI of either 100 or 300 ms. Display 2 contained two neutral faces, with T2 located either in the same or the opposite hemifield to T1.

5.3 Analysis

5.3.1 Behavioural

Behavioural data were analysed on both accuracy and response times using ANOVAs, with emotion (fearful target, fearful distractor, neutral), hemifield (same, opposite), and ISI (100-ms, 300-ms) as within-subjects factors and an alpha level of .05. Across analyses, where the assumption of sphericity was violated, degrees of freedom were adjusted using either Greenhouse-Geisser or Huynh-Feldt corrections; if $\varepsilon > 0.75$, a Huynh-Feldt correction was applied (Field, 2011; Girden, 1992). All post-hoc tests were conducted with Bonferroni correction for multiple comparisons.

5.3.2 EEG

EEG data were analysed using the ERPLAB (http://www.erpinfo.org/erplab/) and EEGLAB (http://sccn.ucsd.edu/eeglab/) toolboxes within MATLAB. Offline referencing was done using the algebraic average of the right and left mastoids. Data were submitted to an IIR Butterworth band-pass filter of 0.1–40 Hz. Filtered data were divided into epochs of 1000 ms, with a pre-stimulus period of 200 ms relative to the onset of the first display, used for baseline correction. Epochs consisting of deflections exceeding +/- 100 μV on all channels and +/- 50 μV on the VEOG and HEOG channels were removed. Visual inspection of epochs was subsequently carried out to ensure artefacts were fully removed. Trials with incorrect responses or responses made outside the response window were also removed from further analyses. Overall, this led to the removal of 35% of all trials. I anticipated such a high quantity of removed trials, and had therefore factored this into the initial computation of total number of trials required to ensure that

each condition contained a minimum of 50 trials for the calculation of the N2pc.[35] The N2pc component was measured from contralateral–ipsilateral difference waveforms in parietal–occipital electrodes (P7/8, P07/08, O1/2) and was analysed separately for T1 and T2.

N2pc onset latencies were determined using a jackknife procedure (Miller, Patterson, & Ulrich, 1998; Ulrich & Miller, 2014)[36] on the difference waveforms (contralateral–ipsilateral) relative to T1 and T2 separately. Nineteen grand-average difference waves were computed for each condition, each excluding one different participant from the original sample. N2pc onset latency was defined as the time at which each subsample difference wave reached 25% of the peak amplitude. Resulting latencies are shown in Table 5-1. Repeated measures ANOVAs were conducted on onset latencies, with within-subjects factors of emotion condition (fearful target, fearful distractor, neutral), hemifield (same, opposite), and ISI (100-ms, 300-ms). Due to the artificial reduction in error variance caused by the jackknife procedure, F values and t values were adjusted in accordance with corrections prescribed by Ulrich and Miller (2014), indicated by F_c and t_c, respectively.

Mean amplitudes were determined for 100-ms time windows separately for T1 and for T2 and separately for each emotion × hemifield × ISI condition in order to account for variation between conditions. For T1, mean amplitudes were entered into a 3 × 2 repeated measures ANOVA, with emotion and ISI as the within-subjects factors. Hemifield was not used here, as it was not defined until the onset of T2. For T2, mean amplitudes were entered into a 3 × 2 × 2 repeated measures ANOVA, with emotion, hemifield, and ISI as within-subjects factors.

[35] The minimum quantity of trials required for the computation of the N2pc was determined after consulting with Professor Martin Eimer.

[36] The benefit of jackknife-based procedures over individual averaged ERPs is the increase of the signal-to-noise ratio. Using averaged waveforms across different participants, rather than those from individual averages, provides a less noisy and therefore more robust assessment of onset latencies.

5.4 Results

5.4.1 Behavioural

For accuracy, results showed a significant main effect of emotion [F (1,18) = 14.21, p < .001, η_p^2 = .42]. Post-hoc tests showed that accuracy was lower on trials containing fearful face targets (M = 79.27% ± SEM = 0.02) compared to trials with fearful face distractors (M = 81.89% ± SEM = 0.02) [t (18) = -4.48, p < .001, d = 1.03, CI = (-0.04, -0.01)] and compared to trials with only neutral faces (M = 81.83% ± SEM = 0.02) [t (18) = -4.49, p < .001, d = 1.03, CI = (-0.04, -0.01)] (Figure 5-2A). The difference in response accuracy was, however, small (2% decrease for fearful face targets). Results also revealed a main effect of ISI [F (1,18) = 6.47, p = .020, η_p^2 = .26], with higher accuracy for the 300-ms ISI condition compared to the 100-ms ISI condition [300-ISI: 82%, CI = (77.80, 86.30)]; 100-ISI: 80%, CI = (75.40, 84.60)] (Figure 5-2B). There were no further main effects or interactions (all p's > .082).

For RTs, ANOVA results revealed a significant hemifield × ISI interaction [F (1,18) = 14.21, p < .001, η_p^2 = .44]. Post-hoc t tests revealed that for the 300-ms ISI condition, RTs were reduced when targets were located in opposite hemifields (M = 752.35 ± SEM = 22.91) compared to same hemifields (M = 762.77 ± SEM = 21.89) [t (18) = 2.81, p = .012, d = .65, CI = (2.63, 18.22)] (Figure 5-2C). There were no further main effects or interactions (all p's > .15).

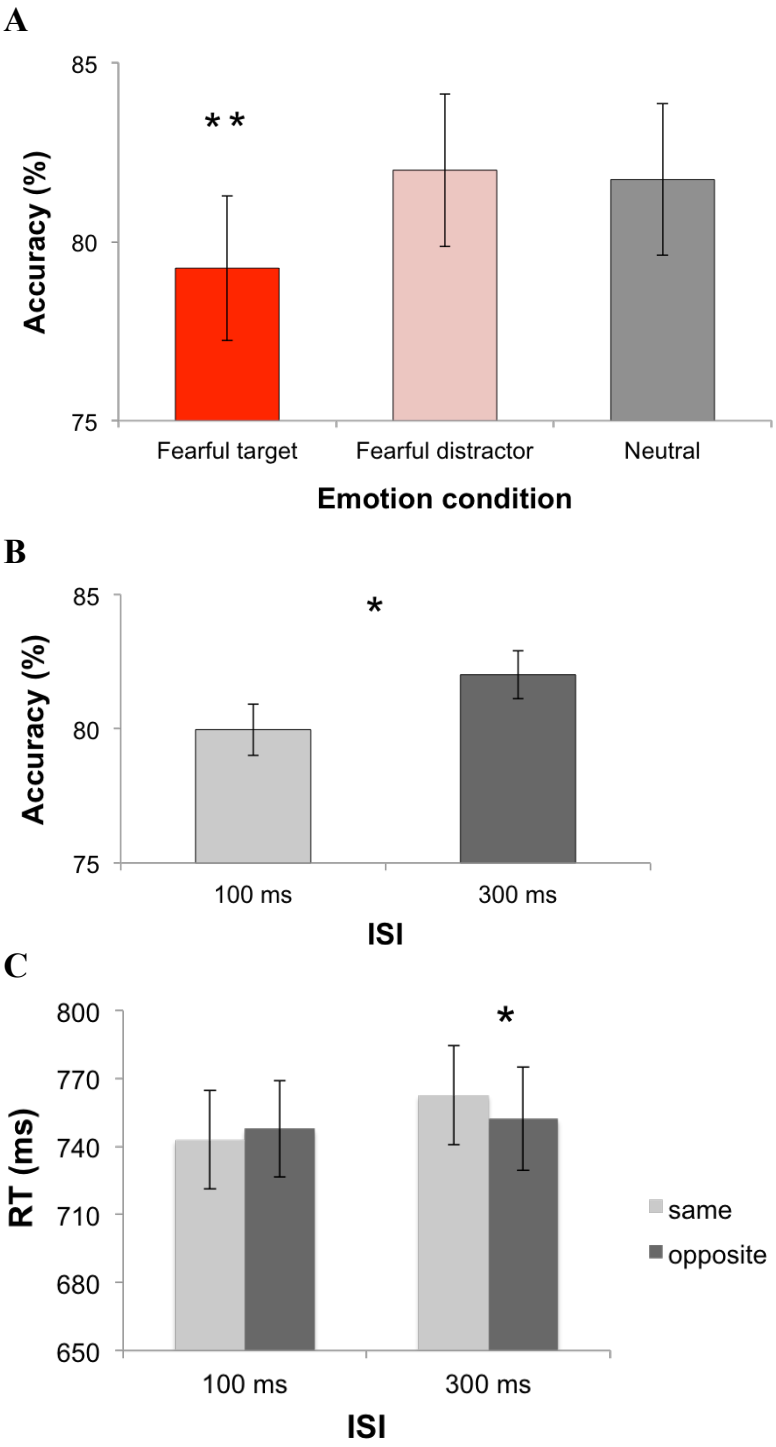


Figure 5-2: Behavioural results: (A) Accuracy was significantly reduced for the fearful face target condition, compared to both the fearful distractor and neutral condition. Asterisks indicate significant differences between emotion conditions ($p \leq .001$). (B) Accuracy was significantly reduced for the 100-ms ISI condition. Asterisk indicates significant differences between ISI conditions ($p \leq .05$). (C) For the 300-ms ISI condition, participants were significantly quicker at responding to T2 when it was located in the opposite hemifield to T1. Asterisk indicates significant differences between emotion conditions ($p \leq .05$).

5.4.2 EEG

Grand-average ERP waveforms time-locked to the onset of Display 1 over posterior electrodes are shown in Figure 5-3. One-sample *t* tests versus zero revealed a significant N2pc, indexed by the contralateral-ipsilateral difference waveform, for T1 in the 100-ms ISI condition [t (18) = -3.96, p = .001, d = 0.90, CI = (-.87, -0.27)] and in the 300-ms ISI condition [t (18) = -3.86, p = .001, d = 1.09, d = 0.88, CI = (-1.15, -0.34)]. Moreover, *t* tests revealed a significant N2pc for T2 for the 100-ms ISI condition [t (18) = -4.23, p = .001, d = 0.97, CI = (-1.37, -0.46)] and for the 300-ms ISI condition [t (18) = -4.07, p = .001, d = 0.93, CI = (-1.28, -0.41)].[37]

The appearance of T2 in the opposite hemifield caused a reversal in polarity. Repeated measures ANOVAs with emotion, hemifield, and ISI as within-subjects factors were conducted on mean amplitudes of difference waveforms for T2, computed relative to T1 (i.e. contralateral and ipsilateral waveforms were defined in relation to T1). Results revealed a main effect of hemifield [F (1, 18) = 18.62, p < .001, η_p^2 = .51], with greater amplitudes for the same hemifield (M = -1.63, ± SEM = 0.28) compared to the opposite hemifield (M = 0.13, ± SEM = 0.20) and a change from a negative to a positive deflection, thus showing the reversal in polarity.

[37] To complement these analyses, *t* tests were conducted using separate contralateral and ipsilateral waveforms (rather than difference waveforms) to directly assess differences as a function of laterality. Results revealed significant differences between contralateral and ipsilateral mean amplitudes for T1 for the 100-ms ISI condition [t (18) = -3.47 p = .003, d = 0.80, CI = (-1.17, -.29)] and the 300-ms ISI condition [t (18) = -3.62, p = .002, d = 0.83, CI = (-1.24, -.33)]. Similarly, *t* tests revealed significant differences in amplitudes for contralateral and ipsilateral waveforms for T2 for the 100-ms ISI condition [t (18) = -4.16 p = .001, d = 0.95, CI = (-2.37, -.78)] and for the 300-ms ISI condition [t (18) = -3.47 p < .001, d = 1.64, CI = (-2.95, -1.61)].

100-ms ISI	
Target 1	
Fearful target	234.5 ± 0.36
Fearful distractor	253.0 ± 0.50
Neutral	220.47 ± 2.03
Target 2	
Fearful target	
same	277.90 ± 0.37
opposite	247.53 ± 1.09
Fearful distractor	
same	280.26 ± 0.55
opposite	244.05 ± 1.47
Neutral	
same	282.47 ± 0.27
opposite	245.74 ± 0.33

300-ms ISI	
Target 1	
Fearful target	247.40 ± 0.83
Fearful distractor	251.55 ± 3.97
Neutral	234.03± 1.27
Target 2	
Fearful target	
same	243.00 ± 0.24
opposite	394.89 ± 4.44
Fearful distractor	
same	242.16 ± 0.22
opposite	419.74 ± 0.46
Neutral	
same	244.32 ± 0.24
opposite	419.58 ± 0.41

Table 5-1: N2pc onset latencies, determined using the jackknife-based procedure, for the different emotion × hemifield conditions, for the 100-ms ISI condition (left) and the 300-ms ISI condition (right).

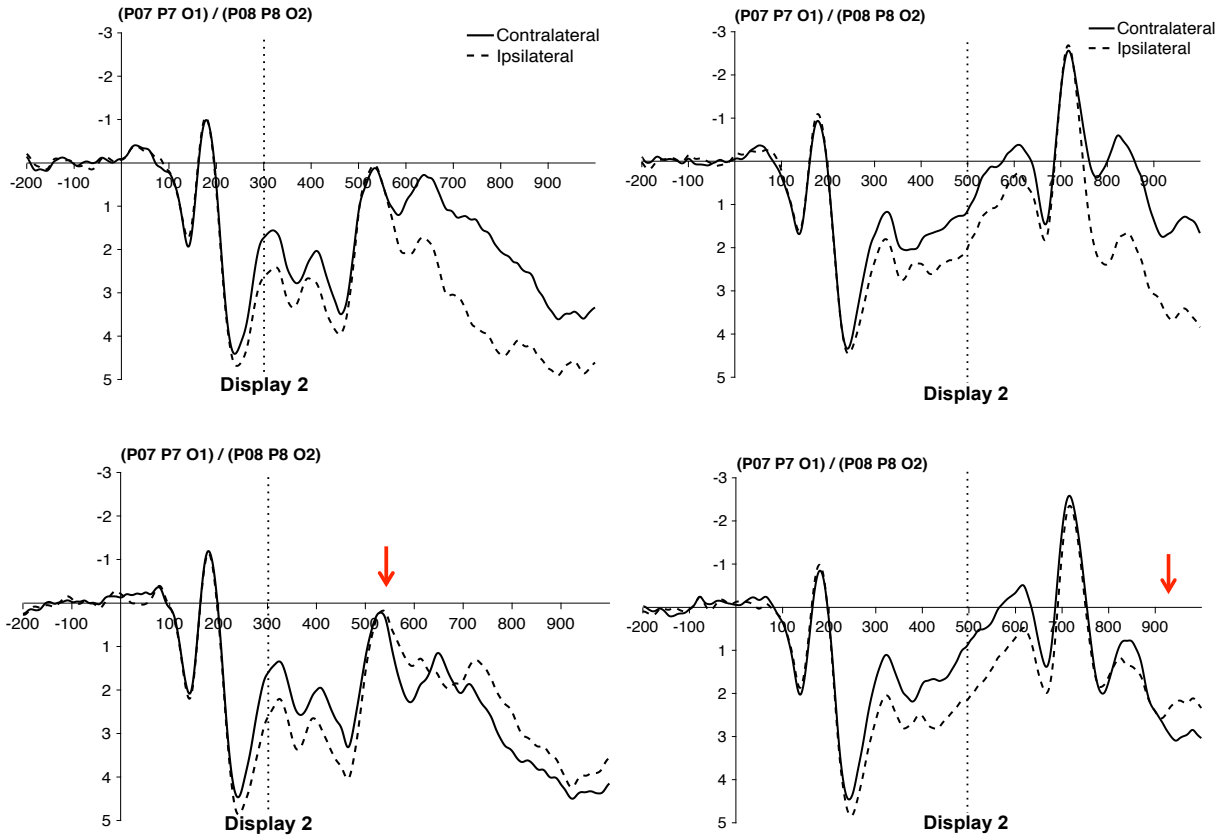


Figure 5-3: Contralateral and ipsilateral waveforms, relative to T1, for same (top) and opposite (bottom) hemifield conditions, for the 100-ms ISI condition (left) and the 300-ms ISI condition (right). The N2pc to T2 reversed polarity (shown by the red arrow) when targets appeared in opposite hemifields. No polarity reversal occurred in the same hemifield conditions.

Target Selection in Display 1

Selection of T1 started at 236 ms in the 100-ms ISI condition and 275 ms in the 300-ms ISI condition, according to the jackknife procedure. ANOVAs revealed no significant effects of onset latencies according to emotion (p = .77), ISI (p = .76), or their interaction (p = .97).

Analyses of mean amplitude for T1 revealed a significant main effect of emotion [F (2, 36) = 3.40, p = .044, η_p^2 = .16]. The main effect was qualified by an interaction between emotion and ISI [F (2, 36) = 4.80, p = .014, η_p^2 = .21]. To clarify this interaction, ANOVAs were conducted separately for each ISI condition, with emotion as the within-subjects factor. Results revealed a significant main effect of emotion for the 100-ms ISI condition [F (2, 36) = 6.65, p = .003, η_p^2 = .27]. Post-hoc paired samples t tests revealed significantly heightened amplitudes to fearful face targets, compared to neutral face targets paired with fearful face distractors [t (18) = -3.00, p = .008, d = 0.69, CI = (-0.73, -0.13)]. Amplitudes in the fearful face target condition were not significantly greater than those in the neutral baseline condition [t (18) = -1.34, p = .20]. Moreover, the N2pc to neutral face targets paired with fearful face distractors showed significantly reduced amplitudes compared to the neutral baseline condition [t (18) = 2.52, p = .021, d = 0.58, CI = (0.05, 0.55)]. Given the diminished N2pc to the neutral face targets, coupled with fearful face distractors, one-sample t tests were conducted to verify that the N2pc was significantly different from zero. Results showed a significant difference [t (18) = -2.70, p = .015, d = 0.62, CI = (-0.99, -0.12)]. Mean amplitudes for T1 for each emotion condition are shown in Table 5-2. Results for the 300-ms ISI condition revealed no main effect of emotion [F (2, 36) = 1.34, p = .27].

	100-ms ISI
	Target 1
Fearful target	-0.986 ± 0.16
Fearful distractor	-0.557 ± 0.21
Neutral	-0.858 ± 0.17

Table 5-2: Mean N2pc amplitudes, in microvolts, are shown for T1 for each emotion condition, with ± *SEM*.

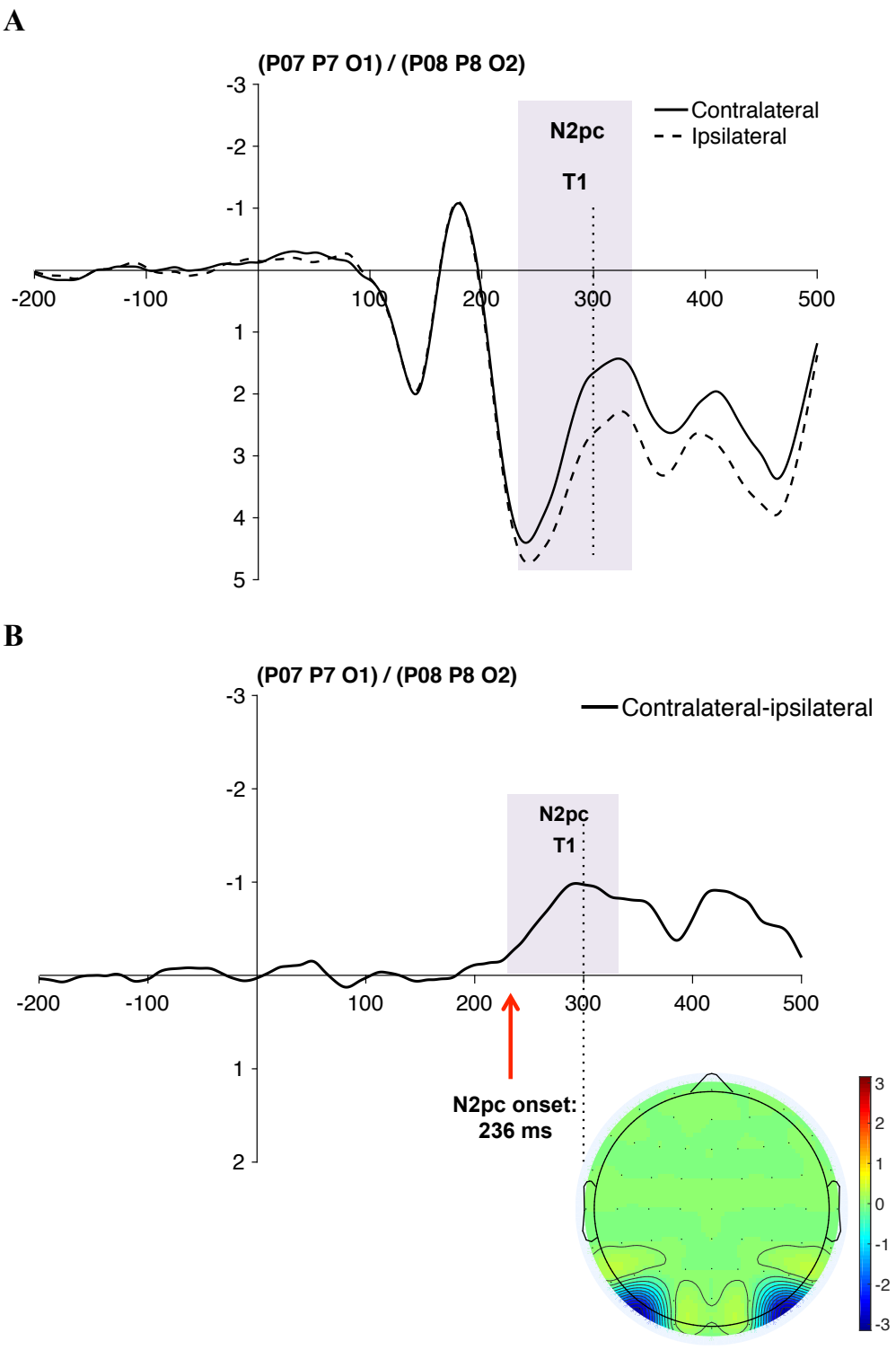


Figure 5-4: 100-ms ISI: (A) Contralateral and ipsilateral posterior-occipital waveforms for T1. This was computed across hemifield conditions, as this condition was only determined at the appearance of T2. The 100-ms time window defined as the N2pc is shown in purple shading. (B) The topography of the difference waveform during the N2pc time window is shown at the bottom. Dotted lines indicate the time point at which Display 2 appeared.

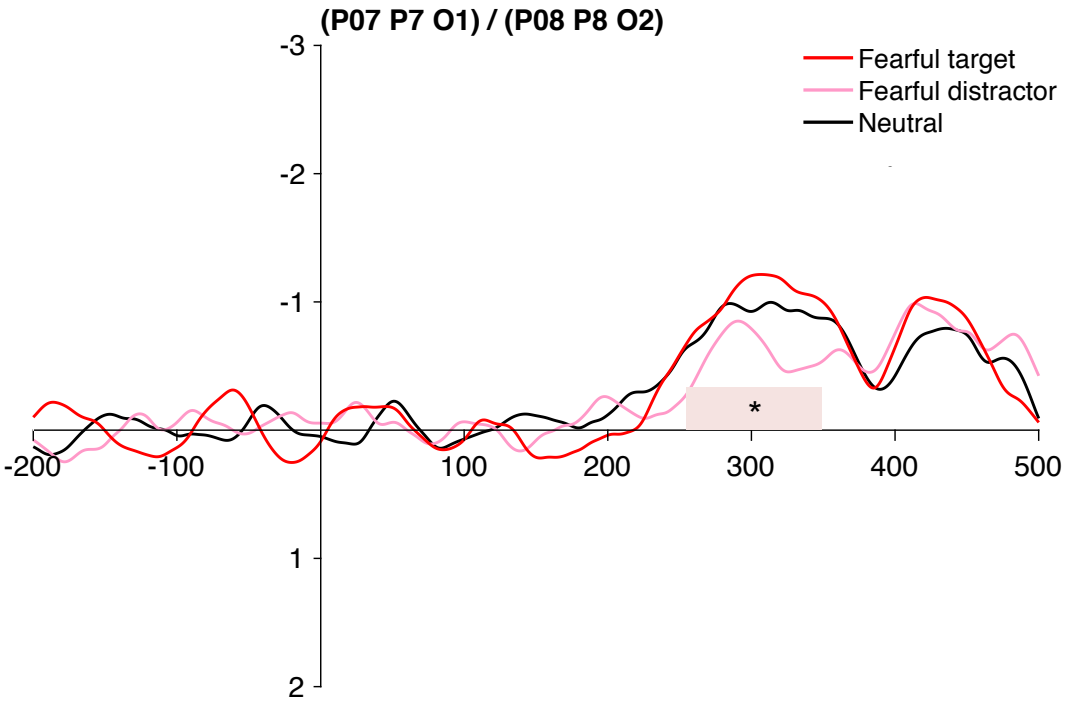


Figure 5-5: Contralateral-minus-ipsilateral difference waveforms for T1 for the three emotion conditions, across hemifield conditions. The shaded area shows the significant main effect of emotion, such that mean N2pc amplitudes for neutral targets paired with fearful distractors were significantly lower compared to both other emotion conditions. Asterisk indicates this main effect ($p \leq .05$).

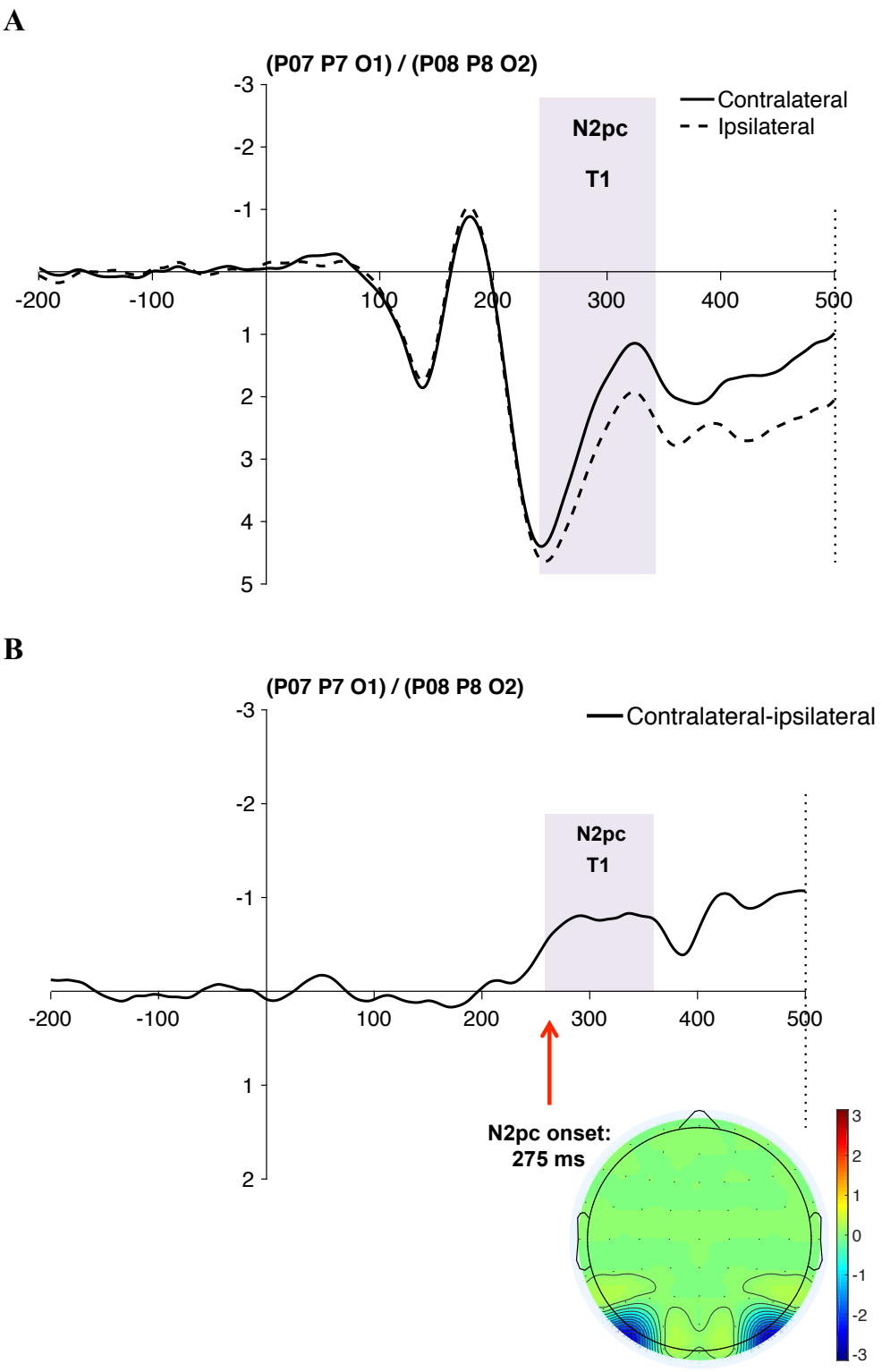


Figure 5-6: 300-ms ISI: (A) Contralateral and ipsilateral posterior-occipital waveforms for T1. This was computed across hemifield conditions. The 100-ms time window defined as the N2pc is shown in purple shading. (B) The topography of the difference waveform during the N2pc time window is shown at the bottom. Dotted lines indicate the time point at which Display 2 appeared.

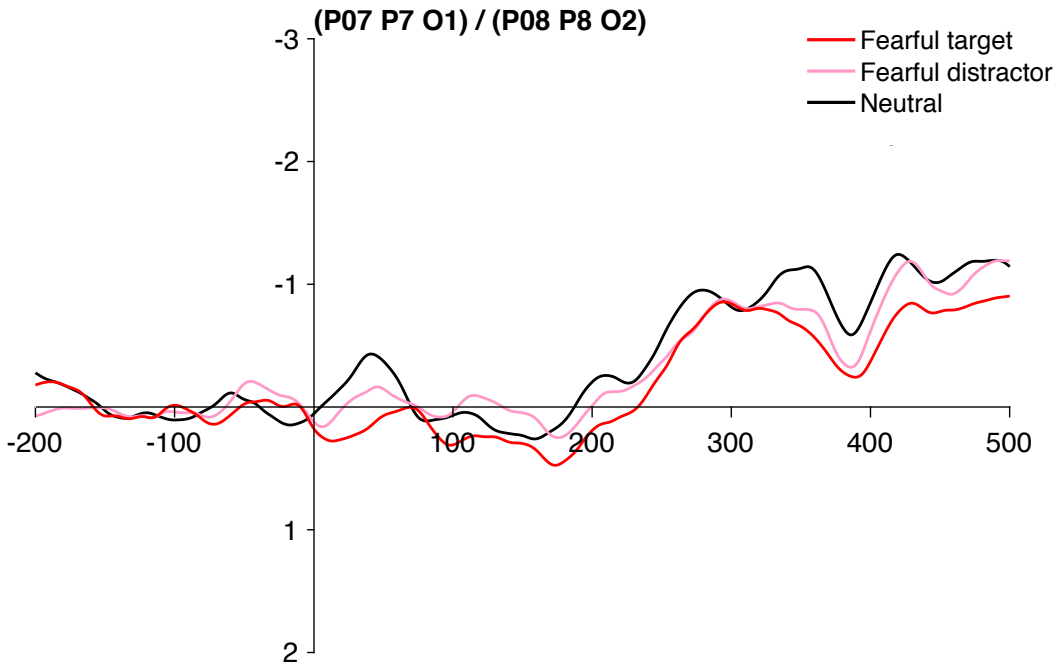


Figure 5-7: Difference waveforms for T1 for the three emotion conditions, across hemifield conditions. There was no main effect of emotion (p = .71).

Target Selection in Display 2

Selection of T2 started at 263 ms post T2-onset in the 100-ms ISI condition and 327 ms in the 300-ms ISI condition, according to the jackknife procedure. Analysis of the N2pc latency for detecting T2 faces revealed a main effect of hemifield [F_c (1,18) = 18.58, p < .001], with delayed onsets when T2 was located in the opposite hemifield to T1 (M = 328.59 ms ± SEM = 0.87) compared to the same hemifield (M = 261.68 ms ± SEM = 0.19). Results also showed a main effect of ISI [F_c (1,18) = 21.83, p < .001], with delayed onsets for the 300-ms ISI condition (M = 327.281 ms ± SEM = 0.76) compared to the 100-ms ISI condition (M = 262.99 ms ± SEM =

0.36). These main effects were qualified by a significant hemifield × ISI interaction [F_c (1,18) = 37.30, $p < .001$]. Post-hoc *t* tests revealed a significantly greater delay in N2pc onset when T2 was located in the opposite, compared to the same, hemifield to T1 in the 300-ms ISI condition (opposite: $M = 411.40$ ms ± $SEM = 1.52$; same: $M = 246.16$ ms ± $SEM = 0.24$) [t_c (18) = 2.17, $p = .044$]. Instead, in the 100-ms ISI condition, onsets were significantly more delayed when T2 appeared in the same hemifield to T1 (same: $M = 280.21$ ms ± $SEM = 0.33$; opposite: $M = 245.77$ ms ± $SEM = 0.75$) [t_c (18) = -2.11, $p = .049$].

Results for N2pc amplitudes showed a significant main effect of hemifield [F (1,18) = 24.23, $p = .012$, $\eta_p^2 = .30$], with heightened amplitudes when T2 was located in the same hemifield as T1 ($M = -1.63$ ± $SEM = 0.28$) compared to the opposite hemifield ($M = -0.98$ ± $SEM = 0.18$). Moreover, results showed a main effect of ISI [F (1,18) = 30.14, $p < .001$, $\eta_p^2 = .63$], with greater amplitudes for the 300-ms ISI condition ($M = -1.69$ ± $SEM = 0.22$) compared to the 100-ms ISI condition ($M = -0.92$ ± $SEM = 0.22$). There were no further main effects or interactions (all p's > .052).

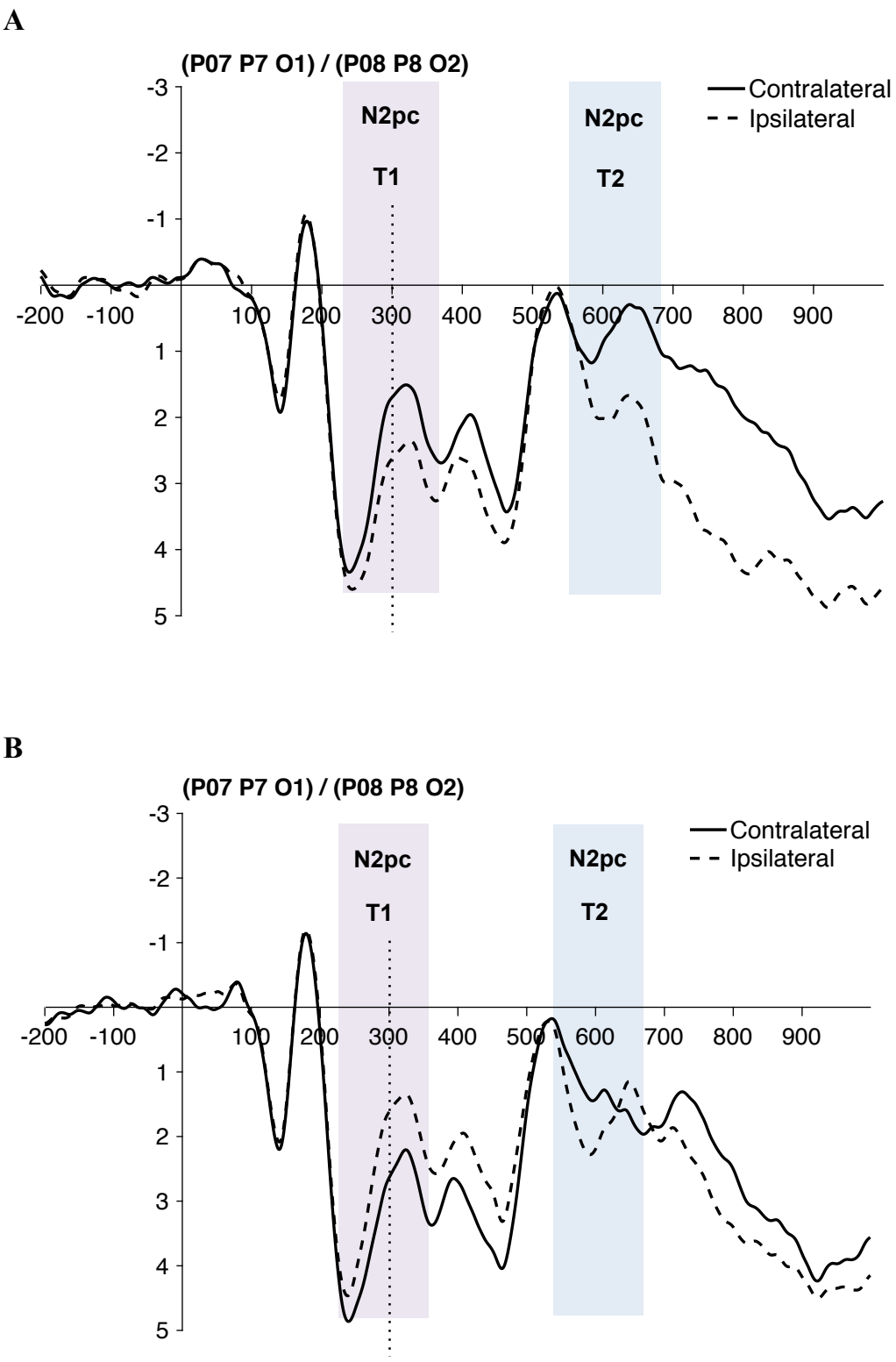


Figure 5-8: 100-ms ISI: (A) Contralateral and ipsilateral waveforms for T2 for the same hemifield condition. (B) Contralateral and ipsilateral waveforms for T2 for the opposite hemifield condition. Dotted lines indicate the time point at which Display 2 appeared.

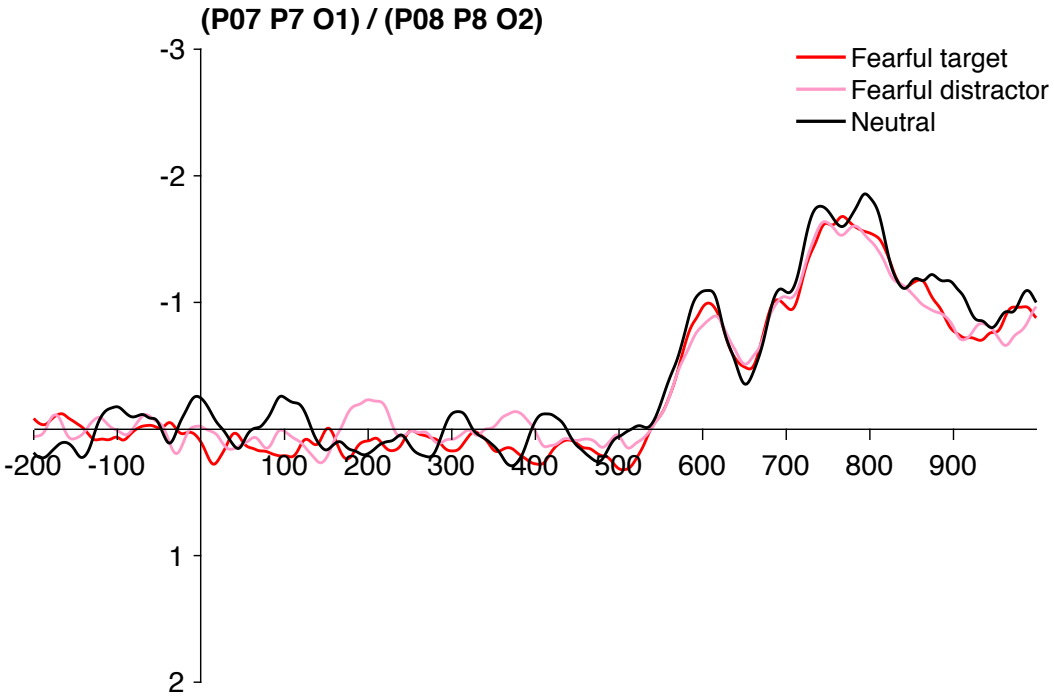


Figure 5-9: 100-ms ISI: Difference waveforms for T2 for the three emotion conditions, across hemifield conditions. There was no main effect of emotion (p = .79).

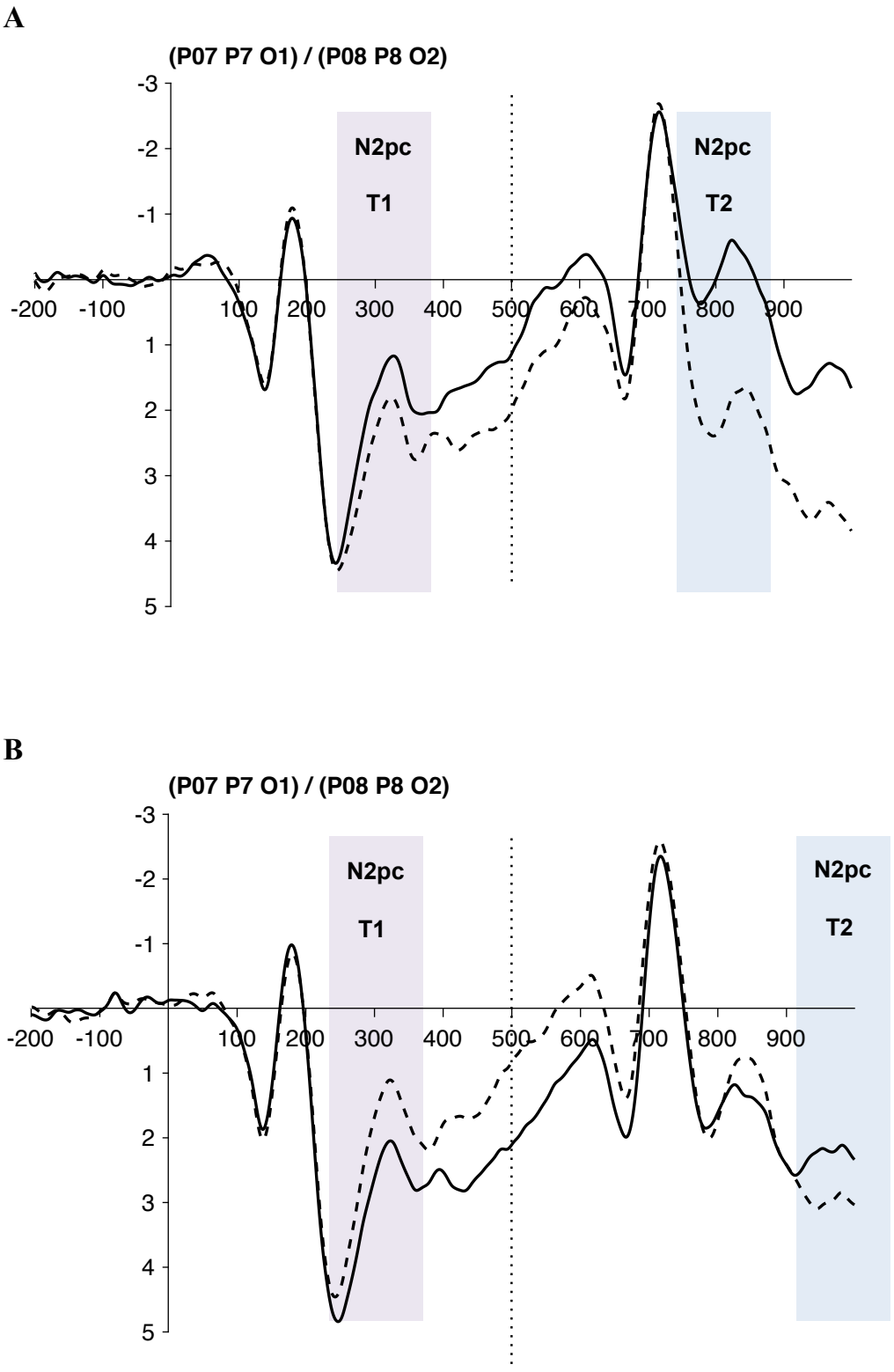


Figure 5-10: 300-ms ISI: (A) Contralateral and ipsilateral waveforms for T2 for the same hemifield condition. (B) Contralateral and ipsilateral waveforms for T2 for the opposite hemifield condition. Dotted lines indicate the time point at which Display 2 appeared.

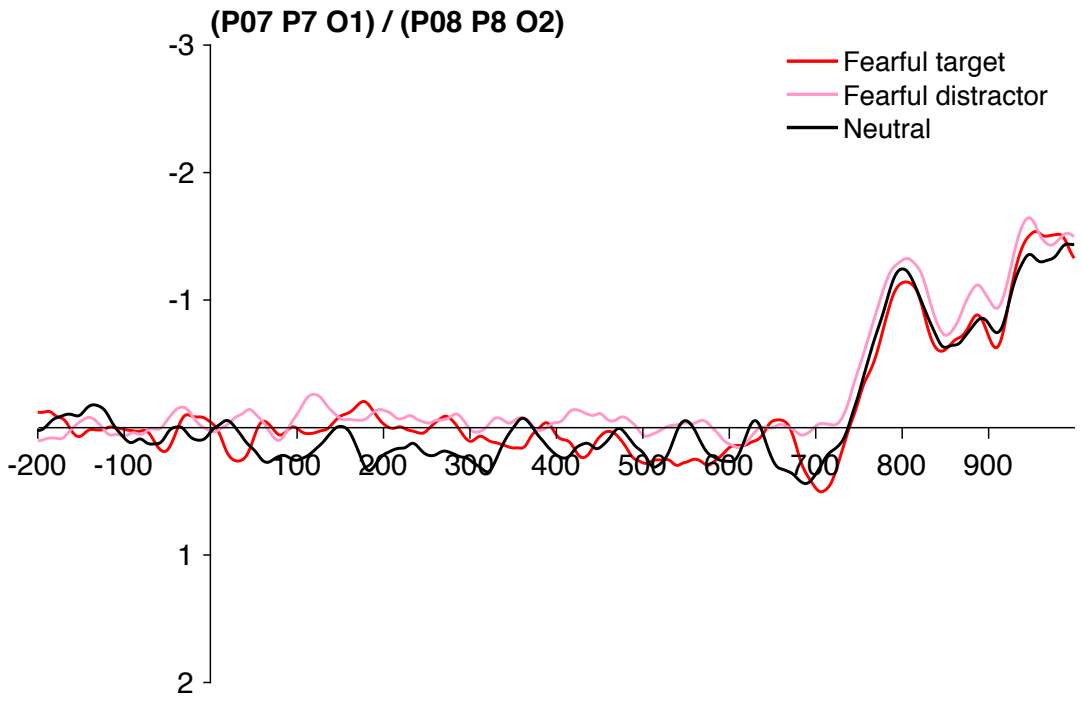


Figure 5-11: 300-ms ISI: Difference waveforms for T2 for the three emotion conditions, across hemifield conditions. There was no main effect of emotion (p = .50).

5.5 Discussion

The current study investigated the degree to which both task-relevant and task-irrelevant fearful faces impacted the ability to redirect attention to a temporally proximate neutral target. The N2pc was used as an index of lateralised attentional selection so as to obtain a precise account of the temporal dynamics of attentional capture by fearful faces. As the study aimed to provide an initial assessment of task efficacy, trait anxiety was not included. The study is thus intended as a basis for future research into how anxiety modulates the reorienting of attention from an initial threatening stimulus.

Overall, results show that attention can be readily redirected from an emotional stimulus to a subsequent neutral stimulus when presented in rapid succession. The reversal in polarity, shown in Figure 5-3, depicts the successful rapid reorientation of attention from T1 to T2. The point of reversal corresponded to the appearance of T2 and was therefore roughly commensurate with ISI, with an additional delay of 165 ms in the 300-ms ISI compared to the 100-ms ISI. Eimer and Grubert (2014) similarly showed that reorientation of attention to a second target was linked to the time at which the target was presented. Moreover, their results revealed that attention was reoriented even when targets temporally overlapped, thus underscoring the speed at which attention can be directed between stimuli.

The manipulation of emotion in the first display revealed that N2pc amplitudes were significantly reduced for neutral face targets paired with fearful face distractors, indicating that task-irrelevant threat captured attention, leaving fewer attentional resources to devote to task-relevant stimuli. Previous studies have similarly found evidence of capture by distracting threat (Eimer & Kiss, 2007; Hodsoll et al., 2011). The reduced amplitude, however, was only evident at the 100-ms ISI. This may indicate that the adverse effects of distracting threat may only occur under conditions of high cognitive load, caused by the relatively greater processing speed required at the short ISI, when resources are taxed to a greater extent.

In my task, it was not possible to separate the potential contributing effects of selecting the task-relevant target from suppressing a distractor that has garnered attention. In principle, the potential known as the distractor positivity (PD) can index the extent to which distractors affected attentional selection of concurrent targets. The component is a positive deflection elicited contralateral to an item requiring active suppression (Gaspelin & Luck, 2018a, 2018b; Hickey, Di Lollo, & McDonald, 2009; Kiss, Grubert, Petersen, & Eimer, 2012). The signal-suppression

hypothesis proposes that salient distractors automatically attract attention, in a bottom-up fashion, but that top-down suppression mechanisms, in accordance with task demands, are able to dampen the automatic access of distractors to attentional resources (Sawaki, Geng, & Luck, 2012; Sawaki & Luck, 2010, 2011). The PD reflects such suppression and has been evidenced to emerge when attentional selection of distractors is deterred. As the current design presented distractors in the opposite hemifield to targets, calculation of the PD would simply reflect the inverse of the N2pc to targets. It is therefore possible that suppression of fearful face distractors contributed to the modulation by emotion conditions, but this could not be tested specifically. Future studies using this task should therefore position distractors and targets in various locations, including along the vertical midline, in order to allow for measurements of the PD, thus providing a better understanding of how the emotionality of distractors modulates top-down suppression.

While task-irrelevant threat detracted from processing of the concurrent neutral target, task-relevant threatening targets did not significantly modulate the N2pc amplitude. That is, fearful face targets did not elicit enhanced N2pc amplitudes, relative to the neutral baseline. These findings deviate from previous reports of enhanced N2pc amplitudes to threatening stimuli (Feldmann-Wüstefeld et al., 2011). The lack of greater attentional capture by task-relevant threat, as indicated by absent amplitude modulations, may be attributable to the input of top-down task demands, rendering targets equally salient, independent of emotionality. This interpretation of results is consistent with previous findings showing contingent capture (Brignani et al., 2010; Folk & Remington, 1998; Folk, Remington, & Johnston, 1992; Lien, Ruthruff, Goodin, & Remington, 2008), and in particular with evidence of reduced capture by fearful faces when detection of these faces was inconsistent with task demands (Glickman & Lamy, 2018; Lien, Taylor, & Ruthruff, 2013).

Contrary to changes in N2pc amplitude, onset latencies did not vary as a function of emotional valence. Previous studies have demonstrated that threatening material elicited earlier onset latencies (Feldmann-Wüstefeld et al., 2011), thereby showing a rapid initial deployment of attention to threat. The current findings of comparable latencies in response to fearful face targets and neutral face targets mirror findings of comparable amplitudes, therefore further indicating that task demands governed attentional selection and thus precluded any additional capture by threat. Moreover, Hickey et al. (2006) showed that a unique singleton distractor elicited an earlier N2pc compared to a concurrent target, suggesting that attention was initially captured by the salient distractor before being reoriented to task-relevant information. Instead, the lack of delay in onset latencies for the neutral face targets paired with the fearful face distractors suggests that, while attentional selection to the targets was impaired, as shown by reduced amplitudes, selection was not delayed. These findings may suggest that top-down task goals initially directed attention to the neutral targets, thereby preventing delayed onsets, but that competing capture by the threatening distractors caused shallower processing of the targets.

Taken together, current findings of emotion modulation of the N2pc suggest that task-irrelevant threat captured attention. As the neutral face targets paired with the fearful face distractors nonetheless exhibited an N2pc, top-down mechanisms of attentional control were able to partially override the attentional capture by task-irrelevant threat. Moreover, the lack of amplitude modulations by the fearful face targets suggests that top-down task demands rendered all target stimuli equally salient, regardless of threat value. That is, target-defining features, i.e. colour, dictated attentional selection and therefore lessened the effects of bottom-up capture by threat.

In most task contexts, both the selection of targets and the suppression of distracting information may contribute to N2pc modulation. Previous findings have shown that the addition of spatially proximate distractors caused an increase in N2pc amplitude to concurrent targets, compared to a no-distractor condition (Luck & Hillyard, 1994; Luck, Chelazzi, Hillyard, & Desimone, 1997). The increased amplitude was therefore interpreted as indicating that the component reflects the suppression of proximal distracting information as a means of facilitating target processing. Eimer (1996) refuted this notion, however, by demonstrating the appearance of a comparable N2pc both in the case of targets presented with multiple distractors and in the case of targets presented with only a single competing distractor located in the opposite hemifield, thus minimising the requirement for local distractor suppression. That is, as the N2pc was elicited independently of the quantity of distractors, the component was interpreted as primarily representing the attentional selection of targets, rather than the suppression of distractors. Current findings may shed light on these competing views. In particular, the postulation that the N2pc signifies the suppression of distractors would entail that the N2pc to the neutral face targets paired with task-irrelevant threat would show a *greater* amplitude, reflecting active suppression of the salient threatening distractors. Thus, findings instead corroborate the notion that the N2pc reflects target selection, with diminished selection of neutral face targets due to competing selection of a salient distracting fearful face.

Results showed no modulations of N2pc amplitudes and latencies to T2 as a function of emotion manipulations in the first display. These findings are in line with the observed lack of attentional capture by initial fearful face targets. Moreover, an absent effect of preceding emotion on T2 is consistent with a study by Stein et al. (2009) that required participants to discriminate the sex of emotional faces, comparable to the task in the current study. Results showed that

fearful faces as T1 did not adversely affect processing of T2, underscoring the role of top-down goals and the corresponding attentional set of participants in guiding attentional capture.

However, as fearful face distractors adversely affected processing of the concurrent neutral face target, it is surprising not to have detected similar adverse effects on T2 processing. In particular, the lacking modulations of N2pc amplitude to T2 differ from results of studies employing RSVP tasks that have evidenced impairments of T2 processing caused by preceding distracting emotional information (Kennedy et al., 2014; Most et al., 2005). Moreover, the current results also diverge from findings of *facilitated* processing of T2 due to an adaptive diffusion of attention in response to threat (Taylor & Whalen, 2014). Instead, the current set of findings indicates that T2 processing was unaffected by preceding emotion. One possibility for the disparate results is the different methodologies employed. The presentation of a series of additional images in RSVP tasks, presented between the critical emotional stimulus and subsequent target, may have potentially further encumbered processing and thereby exacerbated effects of emotion on T2 processing. The restriction of stimuli to a single target and distractor in each pair in the current study limited the amount of processing requirements and thereby may have facilitated the recruitment of top-down control mechanisms to achieve task demands. Similar to the absence of emotion effects on N2pc amplitudes to T2, onset latencies did not vary as a function of threat in the first display. Taken together, these findings indicate that top-down task goals may have overridden any prolonged disruption caused by the threatening distractor. Such top-down control may have therefore allowed participants to readily disengage attention from the fearful faces and to shift attention to T2. That is, task demands prevented adverse effects of threat on T2 processing. Moreover, it is plausible that the ISI durations were sufficiently long so as to prevent a backlog of processing and thereby to preclude congestion of the bottleneck by

fearful faces. The lacking emotion effects cannot be attributed to inadequate salience of the fearful faces, as the amplitude modulation of a neutral face T1 by fearful face distractors provides evidence for emotional salience.

While T2 exhibited no changes in N2pc amplitude as a function of preceding threat, accuracy was diminished in the fearful face target condition. The ostensibly contradictory behavioural findings may instead potentially stem from the heightened perceptual distinction between the fearful face T1 and the neutral face T2, compared to the other two conditions in which the successive targets were both neutral faces. As the task required matching of sex, it is plausible that such matching is more difficult when target faces are perceptually different on account of differing emotional expressions. A study that investigated the competing efficacy of sex and facial expression discriminations showed that the latter took precedence in processing (García-Gutiérrez, Aguado, Romero-Ferreiro, & Pérez-Moreno, 2017), revealing the potency of depicted emotionality in driving perceptual judgements. Thus, the lowered accuracy may not reflect a behavioural index of attentional capture by a fearful face T1 but may instead merely reflect an increased difficulty in comparing sex when targets depict different emotions. Taken together, the lacking N2pc modulations in T2 as a function of emotion manipulation in the first display indicate an efficient redirecting of attention in accordance with task demands. The behavioural findings may instead merely reflect the competition between processing task-irrelevant yet salient facial expressions and task-relevant sex, with ensuing accuracy costs.

Instead, onset latencies to T2 were modulated by hemifield and ISI. For the short ISI condition, N2pc onsets were delayed when T2 was located in the same hemifield to T1. In contrast, onsets in the long-ISI condition were delayed when T2 appeared in the opposite hemifield to T1. These findings suggest that when attention is redirected over a longer time

period, the greater interval between targets positioned in opposite hemifields delayed shifts and thereby attentional selection of T2. Current behavioural findings, however, instead showed reduced RTs when T1 and T2 were located in the opposite hemifield for the 300-ms ISI condition. In contrast, results in the 100-ms ISI condition indicated that when attention must be rapidly redirected between targets, proximate spatial locations render it more difficult to select T2. These results are supported by studies evidencing an 'across-hemifield' advantage for multiple target processing that stems from distinct pools of attentional resources for left and right visual fields, thereby increasing the overall availability of resources for stimuli processing (Reardon, Kelly, & Matthews, 2009; Stormer, Alvarez, & Cavanagh, 2014). Using an attentional tracking task, a study by Alvarez and Cavanagh (2004) revealed that participants were able to track a greater quantity of target stimuli when these were located in opposite, rather than same, hemifields. These findings were interpreted as reflecting the anatomical limitations that render the reorienting of attention between stimuli within the same visual field difficult. Current results of delayed onset latencies similarly suggest that attentional resources are strained when targets occupy the same hemifield, resulting in delayed attentional selection of the second target. Importantly, the delay only occurred in the 100-ms ISI condition and was instead reversed in the 300-ms ISI condition, which indicates that encumbered processing of same-hemifield targets is ameliorated when sufficient time is provided in which resources can be replenished. A previous study showed that the opposite-hemifield benefit was limited to conditions in which stimuli were presented simultaneously, yet disappeared when an ISI of 167 ms was introduced (Sereno & Kosslyn, 1991). These findings indicate that the depletion of resources within a visual field occurs only when stimuli require parallel processing. This notion has been supported by findings showing a stronger opposite-hemifield advantage with greater cognitive load, achieved by virtue of increased task demands (Belger & Banich, 1992; Pollmann, Zaidel, & Von Cramon, 2003). As

increased load requires the recruitment of additional resources, the pooling of interhemispheric resources is especially advantageous. Instead, greater load places further strain on the limited resources available for processing stimuli within a single hemifield. Current results similarly suggest that the ability to redirect attention readily is only constrained by hemifield at a brief ISI, when processing of targets may overlap. It should be noted that the ISI duration of 167 ms in the study by Sereno and Kosslyn (1991), at which the opposite-hemifield advantage disappeared, is similar to the 100-ms ISI in the current study, in which the advantage was still evident. However, the complexity of distinguishing sex, along with the inadvertent processing of emotion, may have required longer processing stages and thus a greater ISI duration to ensure that stages did not overlap.

Results also revealed reduced N2pc amplitudes to T2 in the 100-ms ISI condition, which may be due to the overall greater load imparted by the relatively increased task speed. Moreover, amplitudes were greater for T2 when located in the same hemifield to T1. These findings are in line with the observed earlier onset latencies for the same-hemifield condition for the 300-ms ISI and, taken together, show more efficient attentional reorientation within the same hemifield. However, for the 100-ms ISI, results of latency and amplitude modulations instead suggest that while attentional selection was delayed when T2 was located in the same hemifield to T1, the degree of attention devoted to processing of T2 was greater.

It is important to note that, as a large number of participants were removed due to poor top-down control of their eye movements, their removal may have biased effects. That is, if participants were making more saccades to the emotional faces, they would have consequently shown stronger N2pc modulations in response to the fearful faces. The lack of emotion effects in the current set of results may therefore stem from the exclusion of those participants exhibiting

excessive eye movements. The use of eye tracking in future studies would allow for a separate investigation of threat disruption via an assessment of differential eye movements to fearful versus neutral faces, and potential correlations with trait anxiety.

An interesting avenue for future research is a systematic manipulation of ISI in order to clarify the speed at which attention can be redirected away from threat. The current set of results found differing modulatory effects of emotion on N2pc amplitude of T1 that were restricted to the short ISI. Moreover, the lack of emotion effects on T2 processing may be in part attributable to the ISI durations being sufficiently long, allowing resources to be restored prior to the appearance of T2. The addition of further ISIs can expand this initial investigation of the temporal dynamics of threat biases.

Moreover, an equally important next step is the incorporation of trait anxiety, which may reveal more robust effects of emotion. Anxiety has been shown to amplify the effects of emotional material on subsequent processing, specifically creating greater attentional blinks (Fox et al., 2005; Reinecke, Rinck, & Becker, 2008). Moreover, the N2pc has been used effectively as a marker of anxiety-related attentional biases. Fox, Derakshan, and Shoker (2008) used a spatial-cueing task to investigate differential attentional orienting to angry versus happy faces and revealed a robust N2pc in response to angry faces that was restricted to high trait anxious individuals. Thus, considering evidence that anxiety strongly modulates the degree to which threatening faces capture attention, the absence of higher attentional capture by a fearful face T1 and subsequent effects on processing of T2 may partially be due to the exclusion of trait anxiety as a potential modulating factor. As trait anxiety is marked by impaired top-down attentional control and a corresponding inhibitory deficit (Moran & Moser, 2014), the top-down mechanisms that may have precluded emotion effects in the current set of results may not be as readily

available to anxious participants. Future studies should therefore investigate whether and how individual differences in anxiety modulate current results.

Finally, an interesting direction for future research is an investigation of the effects of cognitive load, particularly how an increase in cognitive load might affect processing of fearful face distractors. For example, in addition to discriminating sex in the current task, participants could be asked to simultaneously discriminate identity, e.g. to determine whether the identities of the target faces matches the identities of targets presented in the previous trial, thus increasing working memory load. As augmenting load depletes processing resources, top-down control mechanisms are weakened, enabling distracting information to capture attention. A study using the dot-probe task with valenced faces showed that when cognitive load was high, due to a concurrent working memory task, N2pc amplitudes to task-irrelevant angry faces increased (Holmes et al., 2014). Introducing load into the current task may reveal greater emotion modulations, particularly to T2. Moreover, cognitive load and trait anxiety interact, such that threat disruption is particularly exacerbated under high load in trait anxious individuals (Bishop et al., 2007), thus substantiating the role of top-down attentional control in anxiety-related threat biases. Hence, further research that administers the task to anxious samples may therefore discover interesting modulating effects of cognitive load.

The study provides an initial account of how task-relevant and task-irrelevant threatening stimuli affect the reorientation of attention to a temporally proximate target. Results demonstrate the combined inputs of bottom-up and top-down mechanisms in dictating capture by threat and the resulting effects on processing of other stimuli. However, future studies should attempt to separate contributions related to target selection versus distractor suppression. In addition, effects of emotional salience may become more potent with the inclusion of anxiety and with additional

ISI durations. The study therefore serves as a foundation for future investigations of the extent to which anxiety-related biases to threat affect the degree of rapid reorientation.

6 General Discussion

The aim of this doctoral research was to develop novel approaches to investigate attentional biases to threatening information that mark trait anxiety. In particular, considering the established potency of endogenous memory cues in guiding attention (Patai et al., 2012; Summerfield et al., 2006, 2011), the series of studies aimed to understand how threatening information interacts with memory signals in directing attention in trait anxious individuals. The attentional biases to threat that characterise clinical and high trait anxiety have thus far been investigated with a limited set of paradigms, such as the dot-probe task and the emotional Stroop task (Bar-Haim et al., 2007; Cisler & Koster, 2010). Although these tasks have yielded informative findings regarding the nature of attentional distortions, weak correlations between tasks and poor internal reliability (Gotlib et al., 2004; Schmukle, 2005; Strauss et al., 2005) leave room for alternative approaches. For this purpose, the current doctoral research developed a new set of tools to investigate how threat interacts with other sources of biases to govern attention in trait anxious individuals.

The studies presented in Chapter 2 incorporated fearful and neutral faces into the contextual cueing paradigm to examine how threat affects implicit learning of contextual regularities and to test whether this is modulated by anxiety. While the pilot study aimed to isolate the effects of emotionality by restricting fearful faces to distracting locations, the approach resulted in a confounding heightened perceptual salience of the neutral face target in arrays of fearful face distractors. To circumvent these confounds, and thereby provide a more clear-cut approach, the primary study used arrays in which all faces were either fearful or neutral, thus matching the emotionality of the target to the surrounding distractors. Results showed that anxiety was marked by an impaired ability to extract contextual regularities in arrays containing

faces, regardless of depicted emotion. Two alternative interpretations were considered. First, anxious participants may have exhibited distraction by face stimuli overall, since these are imbued with social relevance and intrinsic emotionality. Attention in anxious participants may therefore have been captured by the emotion conveyed by all faces, consistent with an emotionality hypothesis (Martin et al., 1991). However, considering that studies presented in subsequent chapters did not reveal an anxiety-related capture by neutral face distractors (discussed below), this possibility is unlikely. The alternative explanation attributes the lacking emotion effects to an interpretation bias, which describes the predilection of anxious individuals to disambiguate information in a negative fashion (Hirsch & Mathews, 1997). While the neutral faces were selected as the baseline condition due to their absent emotionality, this absence inevitably renders them emotionally ambiguous. Thus, anxious participants may have interpreted the ambiguity of the neutral faces as threatening, causing an impairment in learning equivalent to that caused by fearful faces. However, as I only incorporated face stimuli into the cueing paradigm, I cannot ascertain whether the deficit results from attentional disruption by faces or instead from an overall difficulty in learning the covariation among all objects in the environment, independent of emotion. An important next step is to elucidate the anxiety-related impairment via the inclusion of non-face stimuli. Studies have demonstrated deficits in learning and memory functions in anxious individuals. For example, comorbid anxiety and depression have been associated with poor memory recall and a reduction in the amount of new information acquired (Kizilbash, Vanderploeg, & Curtiss, 2002). These deficits are posited to stem from impairments in attentional control mechanisms that enable distracting information to gain ready access to attentional processing (Bishop, 2009; Eysenck et al., 2007). Thus, the inclusion of a non-emotional contextual cueing task as a baseline comparison would inform the breadth of anxiety-related deficits in learning.

Building on these findings of impairments in implicit contextual learning in anxious individuals, the studies presented in Chapter 3 investigated the extent to which adaptive attention-related biases from long-term memories are recruited in the presence of threatening distractors and how such recruitment is modulated by trait anxiety. The adapted emotional memory-guided orienting task enabled the assessment of the extent to which spatial contextual memories can be readily utilised to guide attention to target locations in the context of task-irrelevant threat. The studies therefore explored how distracting threat interacts with endogenous memory cues in individuals displaying a range of trait anxiety levels. In addition, the manipulation of ISI duration across two studies provided an account of the persistence of attentional disruption by threatening distractors even in their absence, reflecting the transient nature of threat in the real world. Results revealed that at long ISI durations, individuals with high levels of trait anxiety showed overall task disruption by fearful face distractors. In contrast, when ISIs were shortened, modulations by both threat and trait anxiety disappeared and instead all participants were able to recruit memories to enable efficient target detection. These findings are consistent with the notion that all individuals, independent of anxiety dispositions, are equipped with adaptive threat detection systems that operate at early processing stages at which threat value is assessed. However, while low anxious individuals are able to dismiss innocuous threat, anxious individuals exhibit excessive and extended engagement with threat. Overall, these results of impaired use of long-term memories complement evidence of impaired recruitment of implicit contextual memories in anxious individuals, presented in Chapter 2, and additionally elucidate the prolonged disruption of threat, supporting the suggestion that ruminative thoughts plague anxious individuals (Fresco, Frankel, Mennin, Turk, & Heimberg, 2002; Harrington & Blankenship, 2002). Similar to studies in Chapter 2, future work should include non-socially relevant and non-emotional distractors, e.g. salient coloured shapes, to assess the extent to which the observed attentional capture by spatial

distractors is driven by emotional content, rather than merely by perceptual salience. While the findings suggest the unique impact of threat in disrupting attention, fearful faces may be more perceptually salient compared to neutral faces, on account of pronounced perceptual features, such as wide eyes and gaping mouths. Thus, the inclusion of salient, non-emotional distractors would clarify the extent to which results were driven exclusively by threat capture.

Taken together, results of the contextual cueing task and the memory-guided orienting task provide converging evidence that memories guide attention in healthy individuals and that the recruitment of these memories is impaired by emotional or threatening distractors in individuals with high levels of trait anxiety. The sole discrepancy in results between studies is the effect of neutral face distractors. While the contextual cueing paradigm showed that neutral faces acted in a similar fashion to their fearful counterparts in disrupting contextual learning, the recruitment of memories in the memory-guided orienting paradigm remained intact in the presence of neutral face distractors. The incongruity may in part stem from specific task parameters, such as the different stimuli durations. As the cueing paradigm presented faces until responses were made, sufficient time may have been available to adopt negative interpretations of ambiguous neutral faces. Instead, the presentation time of 100 ms in the memory-guided orienting task may have precluded such conscious interpretations, resulting in spared task performance in the context of neutral face distractors.

In addition to the primary aim of investigating attentional distortions to salient threat in the context of endogenous memory cues, the doctoral research also examined the extent to which age-normative changes in attentional biases affect attentional capture by threatening information. The study described in Chapter 4 administered the memory-guided orienting task to a sample of older adults with a range of trait anxiety levels. Results revealed that memory-guided orienting

was impeded in high anxious participants when fearful face distractors were presented, thus revealing the endurance of anxiety-related threat biases across age. Other findings, however, were unexpected and remain difficult to interpret, thus demonstrating the need for continued research. Specifically, low anxious participants exhibited a total absence of memory recruitment, operating independently of distractor emotion. These findings contrast with those of a previous study by Salvato et al. (2016) that revealed intact implicit memory use in healthy older adults, using a non-emotional memory-guided orienting paradigm. Moreover, learning and memory tasks did not reveal modulations by trait anxiety, deviating from extant evidence of poorer learning and memory in anxious older adults, which are posited to result from deficits in executive functions, such as inhibitory control (Beaudreau & O'Hara, 2009; Pietrzak et al., 2012; Yochim et al., 2013). While these discrepant results remain puzzling, they nonetheless underscore the need for further research in the anxious older adult population to supplement the scarcity of extant findings.

The final experiment, delineated in Chapter 5, was dedicated to developing an experimental approach to measure the temporal dynamics of engaging with relevant and irrelevant threatening stimuli and the consequences of such threat for adaptive engagement with subsequent stimuli. The task design developed by Eimer and Grubert (2014) was adapted to incorporate emotional stimuli, and the N2pc marker of attentional selection was used to measure the timing and extent of attentional capture by threatening stimuli and by subsequent neutral target stimuli, located in same or opposite hemifields. The study did not take trait anxiety into account, but was intended as a foundation for further research. Results revealed that attentional selection to neutral face targets was attenuated when these targets were paired with fearful face distractors, indexed by reduced N2pc amplitudes. These findings suggest that threat captured

attention and resultantly reduced resources for target processing. Instead, fearful face targets did not exhibit heightened capture, indicating that top-down task demands governed attentional selection and thereby rendered all target stimuli equally salient. Moreover, the ability to redirect attention away from initial threat to a second target remained intact, with onset latencies and mean amplitudes to the subsequent neutral target unaffected by preceding threat. The findings demonstrate the efficacy of the task in tapping into attentional selection of rapidly presented emotional stimuli and pave the way for further research investigating potential modulations by anxiety. In particular, while the non-anxious sample showed no effects of emotion on processing of the temporally proximate target, anxious participants may show a contrasting greater degree of capture by fearful face distractors and a corresponding impaired shifting of attention to the second target. Moreover, while fearful face targets showed little effect in the current results, top-down task demands may not overcome the bottom-up salience of threat in anxious individuals. The EEG study provides a basis for future research and underscores the utility of ERP markers when studying the chronometry of biases to threat. Strengthening the understanding of the time course of these biases by capitalising on the precision afforded by EEG can inform treatment protocols that target early attentional distortions, such as the attention bias modification (Bar-Haim, 2010; Hakamata et al., 2010).

Overall, results across studies contribute to the current knowledge of the nature of attentional biases to threatening information that are a hallmark feature of anxiety (Bar-Haim et al., 2007). The motivation in developing novel approaches stems from the recognition that multiple sources of cues operate concurrently in directing attention. In turn, these cues should be taken into account so as to create an ecologically valid account of attentional patterns in anxiety. The novel approaches therefore expand the context within which anxiety-related biases are

assessed beyond the isolated presentation of valenced stimuli. Results reveal that task-irrelevant threat strongly modulates the extent to which other sources of bias, i.e. implicit memories in contextual learning and long-term memories, are able to influence attention in anxious participants. Such evidence of threat biases overpowering task-relevant memory cues is highly informative in demonstrating the greater weighting of bottom-up salience signals, compared to top-down demands, in anxious individuals, consistent with the Attentional Control Theory (Eysenck et al., 2007).

In addition to informing anxiety research, the current set of results also sheds light on findings from basic cognitive science by highlighting the importance of considering individual differences when analysing task performance. As the samples used throughout this doctoral research consisted of healthy individuals exhibiting non-clinical levels of anxiety, the findings across studies reveal that inter-individual variations can strongly modulate effects. For example, findings of an anxiety-related impairment in contextual cueing are informative in illustrating the benefit of assessing normal levels of anxiety in participants when employing the contextual cueing task. Results by Yamaguchi and Harwood (2015) showed that threatening stimuli incorporated into the cueing paradigm captured attention but did not affect the degree of contextual learning. While the authors interpreted these findings as indicating that threat is processed at pre-attentive stages and thus may not infiltrate subsequent memories, the inclusion of trait anxiety as a covariate may have altered results. In contrast to results of Yamaguchi and Harwood (2015), the study by Szekely, Rajaram, and Mohanty (2016) showed facilitated contextual learning for contexts containing threatening information, thus demonstrating the integration of bottom-up and top-down mechanisms in driving threat biases. However, in line

with the findings in Chapter 2, it is plausible to predict that the observed enhanced learning by threat would be eliminated or reversed in trait anxious individuals.

The current doctoral research not only demonstrates the importance of considering individual differences in trait anxiety but also reveals the strength of stimuli valence in modulating results. For example, Summerfield et al. (2006) provided evidence of a stronger validity effect in the memory-guided orienting paradigm, compared to a visual orienting task. The authors deduced that memories might be more ecologically valid cues in guiding attention, as perceptual cues are instead blunted by the competing visual events occurring in the environment. Results of Chapter 3, however, illustrate how the emotional quality of stimuli, along with variations in trait anxiety, can influence the weighting of visual versus memory cues in guiding attention. Threatening stimuli are salient perceptual events that garner excessive attentional resources in anxious individuals, overriding the efficacy of memory cues. Thus, the relative pull on attention by visual versus memory cues is strongly dictated by both emotional salience of stimuli and individual anxiety dispositions. Similarly, the ERP findings by Eimer and Grubert (2014) showed efficient reorientation of attention between targets. However, Chapter 5 revealed reduced N2pc amplitudes to stimuli paired with distracting threatening information. While results did not evidence adverse effects of such increased attentional capture by threat on subsequent processing, findings reveal the potency of negative emotionality in driving initial attentional capture. Moreover, the inclusion of trait anxiety as a factor may reveal amplified effects of threat capture on processing of subsequent task-relevant stimuli. Thus, the efficient reorientation of attention between successive targets may be modulated as a function of both anxiety levels of participants and threat value of stimuli.

As faces were used throughout this doctoral research, it is important to note that face processing abilities were not assessed. Previous studies have evidenced poorer face identity recognition in individuals with greater levels of social anxiety and thus it is important to consider individual differences in face recognition (Davis et al., 2011). However, as face recognition has been found to not be impaired in general anxiety, as measured using the STAI-T (Davis et al., 2011), I do not predict that my findings were modulated by face processing abilities. Nonetheless, future studies should include measures of face processing in order to assess how potential difficulties in such processing may modulate attention to faces in trait anxiety.

Overall, the doctoral research presented in this thesis is an informative addition to the understanding of attentional biases to threatening information in trait anxiety. The novel tasks developed, via the adaptation of tasks from basic cognitive science, examine these biases in the context of competing endogenous signals and therefore provide an ecologically valid and robust methodology. The exciting findings that my studies have yielded provide fruitful avenues for continued research.

7 References

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional stroop phenomenon: A generic slowdown, not a stroop effect. *Journal of Experimental Psychology: General*, *133*(3), 323–338. http://doi.org/10.1037/0096-3445.133.3.323

Allard, E. S., & Isaacowitz, D. M. (2008). Are preferences in emotional processing affected by distraction? Examining the age-related positivity effect in visual fixation within a dual-task paradigm. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *15*(6), 725–743. http://doi.org/10.1080/13825580802348562

Alvarez, G. A., & Cavanagh, P. (2004). Independent attention resources for the left and right visual hemifields. *Journal of Vision*, *4*(8), 29–29. http://doi.org/10.1167/4.8.29

American Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature1. (1991). *Journal of Clinical Neurophysiology*, *8*(2), 200–202. http://doi.org/10.1097/00004691-199104000-00007

Amir, N., Bomyea, J., & Beard, C. (2010). The effect of single-session interpretation modification on attention bias in socially anxious individuals. *Journal of Anxiety Disorders*, *24*(2), 178–182. http://doi.org/10.1016/j.janxdis.2009.10.005

Andreescu, C., & Varon, D. (2015). New Research on Anxiety Disorders in the Elderly and an Update on Evidence-Based Treatments. *Current Psychiatry Reports*. http://doi.org/10.1007/s11920-015-0595-8

Ansari, T. L., & Derakshan, N. (2011). The neural correlates of cognitive effort in anxiety: Effects on processing efficiency. *Biological Psychology*, *86*(3), 337–348. http://doi.org/10.1016/j.biopsycho.2010.12.013

Armstrong, T., & Olatunji, B. O. (2012). Eye tracking of attention in the affective disorders: A meta-analytic review and synthesis. *Clinical Psychology Review*, *32*(8), 704–723. http://doi.org/10.1016/j.cpr.2012.09.004

Ashley, V., Vuilleumier, P., & Swick, D. (2004). Time course and specificity of event-related potentials to emotional expressions. *Neuroreport*, *15*(1), 211–6. http://doi.org/10.1097/01.wnr.0000091411.19795.f5

Ayers, C. R., Sorrell, J. T., Thorp, S. R., & Wetherell, J. L. (2007). Evidence-Based Psychological Treatments for Late-Life Anxiety, *22*(1), 8–17. http://doi.org/10.1037/0882-7974.22.1.8

Bannerman, R. L., Milders, M., & Sahraie, A. (2010). Attentional Bias to Brief Threat-Related Faces Revealed by Saccadic Eye Movements. *Emotion*, *10*(5), 733–738. http://doi.org/10.1037/a0019354

Bar-Haim, Y. (2010). Research Review: Attention bias modification (ABM): A novel treatment for anxiety disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *51*, 859–870. http://doi.org/10.1111/j.1469-7610.2010.02251.x

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychological Bulletin*, *133*(1), 1–24. http://doi.org/10.1037/0033-2909.133.1.1

References

Bar, M. (2004). Visual objects in context. *Nature Reviews Neuroscience*, *5*, 617–629. http://doi.org/10.1038/nrn1476

Barber, S. J., Opitz, P. C., Martins, B., Sakaki, M., & Mather, M. (2016). Thinking about a limited future enhances the positivity of younger and older adults' recall: Support for socioemotional selectivity theory. *Memory & Cognition*, *44*(6), 869–882. http://doi.org/10.3758/s13421-016-0612-0

Beaudreau, S. A., & O'Hara, R. (2009). The Association of Anxiety and Depressive Symptoms With Cognitive Performance in Community-Dwelling Older Adults. *Psychology and Aging*, *24*(2), 507–512. http://doi.org/10.1037/a0016035

Beaudreau, S. A., & OHara, R. (2008). Late-life anxiety and cognitive impairment: A review. *American Journal of Geriatric Psychiatry*. http://doi.org/10.1097/JGP.0b013e31817945c3

Beck, A., Brown, G., & Steer, R. (1996). BDI-II Manual. *Journal of Health Psychology*. http://doi.org/10.1177/1359105311424470

Beck, A. T., & Clark, D. A. (1997). An information processing model of anxiety: Automatic and strategic processes. *Behaviour Research and Therapy*, *35*(1), 49–58. http://doi.org/10.1016/S0005-7967(96)00069-1

Belger, A., & Banich, M. T. (1992). Interhemispheric interaction affected by computational complexity. *Neuropsychologia*, *30*(10), 923–929. http://doi.org/10.1016/0028-3932(92)90036-L

Bishop, S., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: controlling attention to threat-related stimuli. *Nature Neuroscience*, *7*(2), 184–188. http://doi.org/10.1038/nn1173

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience*, *12*(1), 92–98. http://doi.org/10.1038/nn.2242

Bishop, S. J., Jenkins, R., & Lawrence, A. D. (2007). Neural processing of fearful faces: Effects of anxiety are gated by perceptual capacity limitations. *Cerebral Cortex*, *17*(7), 1595–1603. http://doi.org/10.1093/cercor/bhl070

Blanchard-Fields, F. (2007). Everyday problem solving and emotion: An adult developmental perspective. *Current Directions in Psychological Science*, *16*(1), 26–31. http://doi.org/10.1111/j.1467-8721.2007.00469.x

Bradley, B. P., Mogg, K., & Lee, S. C. (1997). Attentional biases for negative information in induced and naturally occurring dysphoria. *Behaviour Research and Therapy*, *35*(10), 911–927. http://doi.org/10.1016/S0005-7967(97)00053-3

Bradley, B. P., Mogg, K., Millar, N., Bonham-Carter, C., Fergusson, E., Jenkins, J., & Parr, M. (1997). Attentional Biases for Emotional Faces. *Cognition and Emotion*, *11*(1), 25–42. http://doi.org/http://dx.doi.org/10.1080/026999397380014

Bradley, B. P., Mogg, K., & Millar, N. H. (2000). Covert and overt orienting of attention to emotional faces in anxiety. *Cognition & Emotion*, *14*(6), 789–808. http://doi.org/10.1080/026999300501566636

Bradley, B. P., Mogg, K., White, J., Groom, C., & de Bono, J. (1999). Attentional bias for emotional faces in generalized anxiety disorder. *The British Journal of Clinical Psychology / the British Psychological Society*, *38 (Pt 3)*, 267–278. http://doi.org/10.1348/014466599162845

Brassen, S., Gamer, M., & Büchel, C. (2011). Anterior cingulate activation is related to a positivity bias and emotional stability in successful aging. *Biological Psychiatry*, *70*(2), 131–137. http://doi.org/10.1016/j.biopsych.2010.10.013

References

Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. a, Rauch, S. L., Buckner, R. L., … Rosen, B. R. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron*, *17*(5), 875–87. http://doi.org/10.1016/s0896-6273(00)80219-6

Brignani, D., Lepsien, J., & Nobre, A. C. (2010). Purely endogenous capture of attention by task-defining features proceeds independently from spatial attention. *NeuroImage*, *51*(2), 859–866. http://doi.org/10.1016/j.neuroimage.2010.03.029

Broadbent, D., & Broadbent, M. (1988). Anxiety and attentional bias: State and trait. *Cognition & Emotion*, *2*(3), 165–183.

Bryant, C., Jackson, H., & Ames, D. (2008). The prevalence of anxiety in older adults: Methodological issues and a review of the literature. *Journal of Affective Disorders*. http://doi.org/10.1016/j.jad.2007.11.008

Buchanan, T. W., & Lovallo, W. R. (2001). Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology*, *26*(3), 307–317. http://doi.org/10.1016/S0306-4530(00)00058-5

Buratto, L. G., Pottage, C. L., Brown, C., Morrison, C. M., & Schaefer, A. (2014). The effects of a distracting N-back task on recognition memory are reduced by negative emotional intensity. *PLoS ONE*, *9*(10). http://doi.org/10.1371/journal.pone.0110211

Byrne, A., & Eysenck, M. W. (1995). Trait anxiety, anxious mood, and threat detection. *Cognition & Emotion*, *9*(6), 549–562. http://doi.org/10.1080/02699939508408982

Cabeza, R., Ciaramelli, E., Olson, I. R., & Moscovitch, M. (2008). The parietal cortex and episodic memory: An attentional account. *Nature Reviews Neuroscience*. http://doi.org/10.1038/nrn2459

Cabeza, R., Nyberg, L., & Park, D. C. (2009). *Cognitive Neuroscience of Aging: Linking cognitive and cerebral aging*. *Cognitive Neuroscience of Aging: Linking cognitive and cerebral aging*. http://doi.org/10.1093/acprof:oso/9780195156744.001.0001

Calleo, J., Stanley, M. A., Greisinger, A., Wehmanen, O., Johnson, M., Novy, D., … Kunik, M. (2009). Generalized anxiety disorder in older medical patients: Diagnostic recognition, mental health management and service utilization. *Journal of Clinical Psychology in Medical Settings*, *16*(2), 178–185. http://doi.org/10.1007/s10880-008-9144-5

Calvo, M. G., & Avero, P. (2005). Time course of attentional bias to emotional scenes in anxiety: Gaze direction and duration. *Cognition and Emotion*, *19*(3), 433–451. http://doi.org/10.1080/02699930441000157

Calvo, M. G., & Eysenck, M. W. (1992). Anxiety and Performance: The Processing Efficiency Theory. *Cognition and Emotion*, *6*(6), 409–434. http://doi.org/10.1080/02699939208409696

Carstensen, L. L. (1992). Social and emotional patterns in adulthood: support for socioemotional selectivity theory. *Psychology and Aging*, *7*(3), 331–338. http://doi.org/10.1037/0882-7974.7.3.331

Carstensen, L. L., Pasupathi, M., Mayr, U., & Nesselroade, J. R. (2000). Emotional experience in everyday life across the adult life span. *Journal of Personality and Social Psychology*, *79*(4), 644–655. http://doi.org/10.1037//0022-3514.79.4.644

Chapman, A., Devue, C., & Grimshaw, G. M. (2017). Fleeting reliability in the dot-probe task. *Psychological Research*, *0*(0), 1–13. http://doi.org/10.1007/s00426-017-0947-6

Chorpita, B. F., & Barlow, D. H. (1998). The Development of Anxiety: The Role of Control in the Early Environment. *Psychological Bulletin*, *124*(1), 3–21. http://doi.org/10.1037/0033-2909.124.1.3

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, *36*(1), 28–71. http://doi.org/10.1006/cogp.1998.0681

Chun, M. M., & Jiang, Y. (1999). Top-Down Attentional Guidance Based on Implicit Learning of Visual Covariation. *Psychological Science*, *10*(4), 360–365. http://doi.org/10.1111/1467-9280.00168

Chun, M. M., & Jiang, Y. V. (2003). Implicit, long-term spatial contextual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*(2), 224–234. http://doi.org/10.1037/0278-7393.29.2.224

Chun, M. M., & Phelps, E. a. (1999). Memory deficits for implicit contextual information in amnesic subjects with hippocampal damage. *Nature Neuroscience*, *2*(9), 844–7. http://doi.org/10.1038/12222

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology. Human Perception and Performance*, *21*(1), 109–127. http://doi.org/10.1037/0096-1523.21.1.109

Chun, M. M., & Turk-Browne, N. B. (2007). Interactions between attention and memory. *Current Opinion in Neurobiology*, *17*(2), 177–184. http://doi.org/10.1016/j.conb.2007.03.005

Ciaramelli, E., Grady, C. L., & Moscovitch, M. (2008). Top-down and bottom-up attention to memory: a hypothesis (AtoM) on the role of the posterior parietal cortex in memory retrieval. *Neuropsychologia*, *46*(7), 1828–1851. http://doi.org/S0028-3932(08)00110-3 [pii]\r10.1016/j.neuropsychologia.2008.03.022

Cisler, J. M., Bacon, A. K., & Williams, N. L. (2009). Phenomenological characteristics of attentional biases towards threat: A critical review. *Cognitive Therapy and Research*, *33*(2), 221–234. http://doi.org/10.1007/s10608-007-9161-y.Phenomenological

Cisler, J. M., & Koster, E. H. W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review*, *30*(2), 203–216. http://doi.org/10.1016/j.cpr.2009.11.003

Clark, D. M., & Wells, A. (1995). A cognitive model of social phobia. In *Social phobia: Diagnosis, assessment, and treatment* (pp. 69–93). http://doi.org/10.1002/(SICI)1520-6394(1997)5:1<50::AID-DA11>3.0.CO;2-6

Clarke, P. J. F., Notebaert, L., & MacLeod, C. (2014). Absence of evidence or evidence of absence: reflecting on therapeutic implementations of attentional bias modification. *BMC Psychiatry*, *14*, 8. http://doi.org/10.1186/1471-244X-14-8

Conci, M., Müller, H. J., & von Mühlenen, A. (2013). Object-based implicit learning in visual search: Perceptual segmentation constrains contextual cueing. *Journal of Vision*, *13(3)*(15), 1–17. http://doi.org/10.1167/13.3.15.doi

Cooper, R. M., & Langton, S. R. H. (2006). Attentional bias to angry faces using the dot-probe task? It depends when you look for it. *Behaviour Research and Therapy*, *44*(9), 1321–1329. http://doi.org/10.1016/j.brat.2005.10.004

Davachi, L., Mitchell, J. P., & Wagner, A. D. (2003). Multiple routes to memory: Distinct medial temporal lobe processes build item and source memories. *Proceedings of the National Academy of Sciences*, *100*(4), 2157–2162. http://doi.org/10.1073/pnas.0337195100

Davis, J. M., McKone, E., Dennett, H., O'Connor, K. B., O'Kearney, R., & Palermo, R. (2011). Individual differences in the ability to recognise facial identity are associated with social anxiety. *PLoS ONE*, *6*(12). http://doi.org/10.1371/journal.pone.0028800

de Jong, P. J., Koster, E. H. W., van Wees, R., & Martens, S. (2010). Angry Facial Expressions Hamper Subsequent Target Identification. *Emotion*, *10*(5), 727–732. http://doi.org/10.1037/a0019353

De Quervain, D. J. F., Roozendaal, B., Nitsch, R. M., McGaugh, J. L., & Hock, C. (2000). Acute cortisone administration impairs retrieval of long-term declarative memory in humans. *Nature Neuroscience*, *3*(4), 313–314. http://doi.org/10.1038/73873

De Ruiter, C., & Brosschot, J. F. (1994). The emotional stroop interference effect in anxiety: attentional bias or cognitive avoidance? *Behaviour Research and Therapy*, *32*(3), 315–319. http://doi.org/10.1016/0005-7967(94)90128-7

Delphin-Combe, F., Bathsavanis, A., Rouch, I., Liles, T., Vannier-Nitenberg, C., Fantino, B., … Krolak-Salmon, P. (2016). Relationship between anxiety and cognitive performance in an elderly population with a cognitive complaint. *European Journal of Neurology*, *23*(7), 1210–1217. http://doi.org/10.1111/ene.13004

DeLuca, A. K., Lenze, E. J., Mulsant, B. H., Butters, M. A., Karp, J. F., Dew, M. A., … Reynolds, C. F. (2005). Comorbid anxiety disorder in late life depression: Association with memory decline over four years. *International Journal of Geriatric Psychiatry*, *20*(9), 848–854. http://doi.org/10.1002/gps.1366

Demeyer, I., & De Raedt, R. (2013). Attentional Bias for Emotional Information in Older Adults: The Role of Emotion and Future Time Perspective. *PLoS ONE*, *8*(6). http://doi.org/10.1371/journal.pone.0065429

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, 193–222.

Doerksen, S., & Shimamura, A. P. (2001). Source Memory Enhancement for Emotional Words. *Emotion*, *1*(1), 5–11. http://doi.org/10.1037/1528-3542.1.1.5

Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, *11*(3), 357–374. http://doi.org/10.1017/S0140525X00058027

Eimer, M. (1996). The N2pc component as an indicator of attentional selectivity. *Electroencephalography and Clinical Neurophysiology*, *99*(3), 225–234. http://doi.org/10.1016/0013-4694(96)95711-9

Eimer, M., & Grubert, A. (2014). Spatial attention can be allocated rapidly and in parallel to new visual objects. *Current Biology*, *24*(2), 193–198. http://doi.org/10.1016/j.cub.2013.12.001

Eimer, M., & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Neuroreport*, *13*(4), 427–431. http://doi.org/10.1097/00001756-200203250-00013

Eimer, M., Holmes, A., & McGlone, F. P. (2003). The role of spatial attention in the processing of facial expression: an ERP study of rapid brain responses to six basic emotions. *Cognitive, Affective & Behavioral Neuroscience*, *3*(2), 97–110. http://doi.org/10.3758/CABN.3.2.97

Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology*, *74*(1), 108–112. http://doi.org/10.1016/j.biopsycho.2006.06.008

Ekman, P., & Friesen, W. V. (1976). *Pictures of facial affect*. Palo Alto: Consulting Psychologists Press.

Eysenck, H. J., & Eysenck, S. B. G. (1975). *Manual of the Eysenck Personality Questionnaire*. *Journal of Personality Assessment* (Vol. 43). http://doi.org/10.1177/014662168000400106

Eysenck, M., Derakshan, N., Santos, R., & Calvo, M. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336–53. http://doi.org/10.1037/1528-3542.7.2.336

References

Eysenck, M. W., Mogg, K., May, J., Richards, A., & Mathews, A. (1991). Bias in interpretation of ambiguous sentences related to threat in anxiety. *Journal of Abnormal Psychology*, *100*(2), 144–150. http://doi.org/10.1037/0021-843X.100.2.144

Falkenstein, M., Hohnsbein, J., & Hoormann, J. (1994). Effects of choice complexity on different subcomponents of the late positive complex of the event-related potential. *Electroencephalography and Clinical Neurophysiology/ Evoked Potentials*, *92*(2), 148–160. http://doi.org/10.1016/0168-5597(94)90055-8

Feldmann-Wüstefeld, T., Schmidt-Daffy, M., & Schubö, A. (2011). Neural evidence for the threat detection advantage: Differential attention allocation to angry and happy faces. *Psychophysiology*, *48*(5), 697–707. http://doi.org/10.1111/j.1469-8986.2010.01130.x

Fenker, D. B., Heipertz, D., Boehler, C. N., Schoenfeld, M. A., Noesselt, T., Heinze, H. J., … Hopf, J. M. (2010). Mandatory processing of irrelevant fearful face features in visual search. *Journal of Cognitive Neuroscience*, *22*(12), 2926–2938. http://doi.org/10.1162/jocn.2009.21340

Field, A. (2011). *Discovering Statistics Using*. *Statistics* (Vol. 58). http://doi.org/10.1234/12345678

Fleischman, D. A., Wilson, R. S., Gabrieli, J. D. E., Bienias, J. L., & Bennett, D. A. (2004). A longitudinal study of implicit and explicit memory in old persons. *Psychology and Aging*, *19*(4), 617–625. http://doi.org/10.1037/0882-7974.19.4.617

Folk, C. L., & Remington, R. W. (1998). Selectivity in attentional capture by featural singletons. *... of Experimental Psychology: Human Perception and ...*, *24*(3), 847–858.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary Covert Orienting Is Contingent on Attentional Control Settings. *Journal of Experimental Psychology: Human Perception and Performance*, *18*(4), 1030–1044. http://doi.org/10.1037/0096-1523.18.4.1030

Forster, S., Nunez-Elizalde, A. O., Castle, E., & Bishop, S. J. (2014). Moderate threat causes longer lasting disruption to processing in anxious individuals. *Frontiers in Human Neuroscience*, *8*(August), 626. http://doi.org/10.3389/fnhum.2014.00626

Fox, E. (2002). Processing emotional facial expressions: the role of anxiety and awareness. *Cognitive, Affective & Behavioral Neuroscience*, *2*(1), 52–63. http://doi.org/10.1080/02699930143000527

Fox, E. (2008). Cognition & Emotion Attentional bias in anxiety: A defective inhibition hypothesis Attentional Bias in Anxiety: A Defective Inhibition Hypothesis. *Cognition and Emotion*, *1*(82), 165–195. http://doi.org/10.1080/02699939408408934

Fox, E., Derakshan, N., & Shoker, L. (2008). Trait anxiety modulates the electrophysiological indices of rapid spatial orienting towards angry faces. *NeuroReport*, *19*(3), 259–263. http://doi.org/10.1097/WNR.0b013e3282f53d2a

Fox, E., Griggs, L., & Mouchlianitis, E. (2007). The Detection of Fear-Relevant Stimuli: Are Guns Noticed as Quickly as Snakes? *Emotion*, *7*(4), 691–696. http://doi.org/10.1037/1528-3542.7.4.691

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *J Exp Psychol Gen*. http://doi.org/10.1037/0096-3445.130.4.681

Fox, E., Russo, R., & Georgiou, G. (2005). Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, & Behavioral Neuroscience*, *5*(4), 396–404. http://doi.org/10.3758/CABN.5.4.396

Fox, L. S., & Knight, B. G. (2005). The effects of anxiety on attentional processes in older adults. *Aging & Mental Health*, *9*(6), 585–593. http://doi.org/10.1080/13607860500294282

Fresco, D. M., Frankel, A. N., Mennin, D. S., Turk, C. L., & Heimberg, R. G. (2002). Distinct and Overlapping Features of Rumination andWorry: The Relationship of Cognitive Production to Negative Affective States. *Cognitive Therapy and Research*, *26*(2), 179–188. http://doi.org/10.1023/A

Fuggetta, G. (2006). Cortico-Cortical Interactions in Spatial Attention: A Combined ERP/TMS Study. *Journal of Neurophysiology*, *95*(5), 3277–3280. http://doi.org/10.1152/jn.01273.2005

Gable, P., & Harmon-Jones, E. (2010). The blues broaden, but the nasty narrows: Attentional consequences of negative affects low and high in motivational intensity. *Psychological Science*, *21*(2), 211–215. http://doi.org/10.1177/0956797609359622

Gajewski, P. D., & Falkenstein, M. (2018). ERP and Behavioral Effects of Physical and Cognitive Training on Working Memory in Aging: A Randomized Controlled Study. *Neural Plasticity*, *2018*, 3454835. http://doi.org/10.1155/2018/3454835

García-Gutiérrez, A., Aguado, L., Romero-Ferreiro, V., & Pérez-Moreno, E. (2017). Discrimination of face gender and expression under dual-task conditions. *Attention, Perception, and Psychophysics*, *79*(2), 614–627. http://doi.org/10.3758/s13414-016-1236-y

Gaspelin, N., & Luck, S. J. (2018a). Combined Electrophysiological and Behavioral Evidence for the Suppression of Salient Distractors. *Journal of Cognitive Neuroscience*, 1–16. http://doi.org/10.1162/jocn_a_01279

Gaspelin, N., & Luck, S. J. (2018b). The Role of Inhibition in Avoiding Distraction by Salient Stimuli. *Trends in Cognitive Sciences*, *22*(1), 79–92. http://doi.org/10.1016/j.tics.2017.11.001

Gazzaley, A., & Nobre, A. C. (2012). Top-down modulation: Bridging selective attention and working memory. *Trends in Cognitive Sciences*, *16*(2), 129–135. http://doi.org/10.1016/j.tics.2011.11.014

Geyer, T., Zehetleitner, M., & Müller, H. J. (2010). Contextual cueing of pop-out visual search: When context guides the deployment of attention. *Journal of Vision*, *10*(2010), 20. http://doi.org/10.1167/10.5.20

Gilboa-Schechtman, E., Foa, E. B., & Amir, N. (1999). Attentional biases for facial expressions in social phobia: The face-in-the-crowd paradigm. *Cognition and Emotion*, *13*(3), 305–318. http://doi.org/10.1080/026999399379294

Giovanello, K. S., Kensinger, E. A., Wong, A. T., & Schacter, D. L. (2010). Age-related neural changes during memory conjunction errors. *Journal of Cognitive Neuroscience*, *22*(7), 1348–1361. http://doi.org/10.1162/jocn.2009.21274

Girden, E. (1992). ANOVA: Repeated Measures. *Technometrics*, *35*(4), 77. http://doi.org/10.2307/1270301

Glickman, M., & Lamy, D. (2018). Attentional capture by irrelevant emotional distractor faces is contingent on implicit attentional settings. *Cognition and Emotion*, *32*(2), 303–314. http://doi.org/10.1080/02699931.2017.1301883

Gotlib, I. H., Kasch, K. L., Traill, S., Arnow, B. A., Joormann, J., & Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *Journal of Abnormal Psychology*, *113*(3), 386–398. http://doi.org/10.1037/0021-843X.113.3.386

Grafton, B., MacLeod, C., Rudaizky, D., Holmes, E. A., Salemink, E., Fox, E., & Notebaert, L. (2017). Confusing procedures with process when appraising the impact of cognitive bias modification on emotional vulnerability. *British Journal of Psychiatry*, *211*(5), 266–271.

http://doi.org/10.1192/bjp.bp.115.176123
Green, J. S., Magee, J. C., Steiner, A. R. W., & Teachman, B. A. (2017). When the "Golden Years" turn blue. *International Journal of Behavioral Development*, *41*(2), 295–307. http://doi.org/10.1177/0165025415613855
Grillon, C. (2002). Associative learning deficits increase symptoms of anxiety in humans. *Biological Psychiatry*, *51*(11), 851–858. http://doi.org/10.1016/S0006-3223(01)01370-1
Grimshaw, G. M., Foster, J. J., & Corballis, P. M. (2014). Frontal and parietal EEG asymmetries interact to predict attentional bias to threat. *Brain and Cognition*, *90*, 76–86. http://doi.org/10.1016/j.bandc.2014.06.008
Gross, J. J., Carstensen, L. L., Pasupathi, M., Tsai, J., Skorpen, C. G., & Hsu, A. Y. C. (1997). Emotion and aging: Experience, expression, and control. *Psychology and Aging*, *12*(4), 590–599. http://doi.org/10.1037/0882-7974.12.4.590
Grubert, A., & Eimer, M. (2015). Rapid parallel attentional target selection in single-color and multiple-color visual search. *Journal of Experimental Psychology. Human Perception and Performance*, *41*(1), 86–101. http://doi.org/10.1037/xhp0000019
Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J. C., Fox, N. a., Leibenluft, E., … Pine, D. S. (2010). Attention bias modification treatment: A meta-analysis toward the establishment of novel treatment for anxiety. *Biological Psychiatry*, *68*(11), 982–990. http://doi.org/10.1016/j.biopsych.2010.07.021
Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, *5*(9), 394–400. http://doi.org/10.1016/S1364-6613(00)01707-1
Harrington, J. A., & Blankenship, V. (2002). Ruminative thoughts and their relation to depression and anxiety. *Journal of Applied Social Psychology*, *32*(3), 465–485. http://doi.org/10.1111/j.1559-1816.2002.tb00225.x
Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*(1), 163–169. http://doi.org/10.1037/0278-7393.17.1.163
Hazlett-Stevens, H., & Craske, M. G. (2003). the Catastrophizing Worry Process in Generalized Anxiety Disorder: a Preliminary Investigation of an Analog Population. *Behavioural and Cognitive Psychotherapy*, *31*(4), 387–401. http://doi.org/10.1017/S1352465803004016
Hendriks, G. J., Oude Voshaar, R. C., Keijsers, G. P. J., Hoogduin, C. A. L., & Van Balkom, A. J. L. M. (2008). Cognitive-behavioural therapy for late-life anxiety disorders: A systematic review and meta-analysis. *Acta Psychiatrica Scandinavica*, *117*(6), 403–411. http://doi.org/10.1111/j.1600-0447.2008.01190.x
Hickey, C., Di Lollo, V., & McDonald, J. J. (2009). Electrophysiological indices of target and distractor processing in visual search. *Journal of Cognitive Neuroscience*, *21*(4), 760–775. http://doi.org/10.1162/jocn.2009.21039
Hickey, C., McDonald, J. J., & Theeuwes, J. (2006). Electrophysiological evidence of the capture of visual attention. *Journal of Cognitive Neuroscience*, *18*(4), 604–613.
Hirsch, C., & Mathews, A. (1997). Interpretative inferences when reading about emotional events. *Behaviour Research and Therapy*, *35*(12), 1123–1132. http://doi.org/10.1016/S0005-7967(97)00069-7
Hodsoll, S., Viding, E., & Lavie, N. (2011). Attentional capture by irrelevant emotional distractor faces. *Emotion (Washington, D.C.)*, *11*(2), 346–353. http://doi.org/10.1037/a0022771
Holmes, A., Bradley, B. P., Kragh Nielsen, M., & Mogg, K. (2009). Attentional selectivity for emotional faces: Evidence from human electrophysiology. *Psychophysiology*, *46*(1), 62–68. http://doi.org/10.1111/j.1469-8986.2008.00750.x

Holmes, A., Mogg, K., de Fockert, J., Nielsen, M. K., & Bradley, B. P. (2014). Electrophysiological evidence for greater attention to threat when cognitive control resources are depleted. *Cognitive, Affective & Behavioral Neuroscience*, *14*, 827–35. http://doi.org/10.3758/s13415-013-0212-4

Holmes, A., Nielsen, M. K., Tipper, S., & Green, S. (2009). An electrophysiological investigation into the automaticity of emotional face processing in high versus low trait anxious individuals. *Cognitive, Affective, & Behavioral Neuroscience*, *9*(3), 323–334. http://doi.org/10.3758/CABN.9.3.323

Holmes, A., Vuilleumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: Evidence from event-related brain potentials. *Cognitive Brain Research*, *16*(2), 174–184. http://doi.org/10.1016/S0926-6410(02)00268-9

Hopf, J.-M. (2004). Attention to Features Precedes Attention to Locations in Visual Search: Evidence from Electromagnetic Brain Responses in Humans. *Journal of Neuroscience*, *24*(8), 1822–1832. http://doi.org/10.1523/JNEUROSCI.3564-03.2004

Hopf, J. M., Luck, S. J., Girelli, M., Hagner, T., Mangun, G. R., Scheich, H., & Heinze, H. J. (2000). Neural sources of focused attention in visual search. *Cerebral Cortex (New York, NY : 1991)*, *10*(12), 1233–1241. http://doi.org/10.1093/cercor/10.12.1233

Ikeda, K., Sugiura, A., & Hasegawa, T. (2013). Fearful faces grab attention in the absence of late affective cortical responses. *Psychophysiology*, *50*(1), 60–69. http://doi.org/10.1111/j.1469-8986.2012.01478.x

Ikeda, M., Iwanaga, M., & Seiwa, H. (1996). Test anxiety and working memory system. *Perceptual and Motor Skills*, *82*(3 Pt 2), 1223–31. http://doi.org/10.2466/pms.1996.82.3c.1223

Isaacowitz, D. M., Toner, K., Goren, D., & Wilson, H. R. (2008). Looking while unhappy: Mood-congruent gaze in young adults, positive gaze in older adults. *Psychological Science*, *19*(9), 848–853. http://doi.org/10.1111/j.1467-9280.2008.02167.x

Jeste, D. V., Blazer, D. G., & First, M. (2005). Aging-related diagnostic variations: Need for diagnostic criteria appropriate for elderly psychiatric patients. *Biological Psychiatry*. http://doi.org/10.1016/j.biopsych.2005.02.004

Jiang, Y., & Chun, M. M. (2001). Selective attention modulates implicit learning. *The Quarterly Journal of Experimental Psychology*, *54A*(4), 1105–1124. http://doi.org/10.1080/0272498004200051

Jones, G. V., Stacey, H., & Martin, M. (2002). Exploring the intensity paradox in emotional Stroop interference. *Cognitive Therapy and Research*, *26*(6), 831–839. http://doi.org/10.1023/A:1021297602253

Kappenman, E. S., MacNamara, A., & Proudfit, G. H. (2013). Electrocortical evidence for rapid allocation of attention to threat in the dot-probe task. *Social Cognitive and Affective Neuroscience*, *10*(4), 577–583. http://doi.org/10.1093/scan/nsu098

Kennedy, B. L., Rawding, J., Most, S. B., & Hoffman, J. E. (2014). Emotion-induced blindness reflects competition at early and late processing stages: An ERP study. *Cognitive, Affective and Behavioral Neuroscience*, *14*(4), 1485–1498. http://doi.org/10.3758/s13415-014-0303-x

Kensinger, E. A., & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition*, *31*(8), 1169–1180. http://doi.org/10.3758/BF03195800

Kensinger, E. A., & Corkin, S. (2004). Two routes to emotional memory: distinct neural processes for valence and arousal. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(Track II), 3310–3315.

http://doi.org/10.1073/pnas.0306408101
Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2006). Memory for specific visual details can be enhanced by negative arousing content. *Journal of Memory and Language*, *54*(1), 99–112. http://doi.org/10.1016/j.jml.2005.05.005
Kensinger, E. A., Garoff-Eaton, R. J., & Schacter, D. L. (2007). Effects of emotion on memory specificity: Memory trade-offs elicited by negative visually arousing stimuli. *Journal of Memory and Language*, *56*(4), 575–591. http://doi.org/10.1016/j.jml.2006.05.004
Kessels, R. P. C., Boekhorst, S. Te, & Postma, A. (2005). The contribution of implicit and explicit memory to the effects of errorless learning: a comparison between young and older adults. *Journal of the International Neuropsychological Society : JINS*, *11*, 144–151. http://doi.org/10.1017/S1355617705050174
Kindt, M., Bierman, D., & Brosschot, J. F. (1996). Stroop versus Stroop: Comparison of a card format and a single-trial format of the standard color-word Stroop task and the emotional Stroop task. *Personality and Individual Differences*, *21*(5), 653–661. http://doi.org/10.1016/0191-8869(96)00133-X
Kirschbaum, C., Wolf, O. T., May, M., Wippich, W., & Hellhammer, D. H. (1996). Stress- and treatment-induced elevations of cortisol levels associated with impaired declarative memory in healthy adults. *Life Sciences*, *58*(17), 1475–1483. http://doi.org/10.1016/0024-3205(96)00118-X
Kiss, M., Grubert, A., Petersen, A., & Eimer, M. (2012). Attentional capture by salient distractors during visual search is determined by temporal task demands. *Journal of Cognitive Neuroscience*, *24*(3), 749–759. http://doi.org/10.1162/jocn_a_00127
Kiss, M., Van Velzen, J., & Eimer, M. (2008). The N2pc component and its links to attention shifts and spatially selective visual processing. *Psychophysiology*, *45*(2), 240–249. http://doi.org/10.1111/j.1469-8986.2007.00611.x
Kizilbash, A. H., Vanderploeg, R. D., & Curtiss, G. (2002). The effects of depression and anxiety on memory performance. *Archives of Clinical Neuropsychology : The Official Journal of the National Academy of Neuropsychologists*, *17*(1), 57–67. http://doi.org/10.1016/S0887-6177(00)00101-3
Knight, M., Seymour, T. L., Gaunt, J. T., Baker, C., Nesmith, K., & Mather, M. (2007). Aging and goal-directed emotional attention: distraction reverses emotional biases. *Emotion (Washington, D.C.)*, *7*(4), 705–714. http://doi.org/10.1037/1528-3542.7.4.705
Koster, E. H. W., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Does imminent threat capture and hold attention? *Emotion (Washington, D.C.)*, *4*(3), 312–317. http://doi.org/10.1037/1528-3542.4.3.312
Koster, E. H. W., Crombez, G., Verschuere, B., & Houwer, J. De. (2004). Selective attention to threat in the dot probe paradigm : differentiating vigilance and difficulty to disengage, *42*, 1183–1192. http://doi.org/10.1016/j.brat.2003.08.001
Koster, E. H. W., Crombez, G., Verschuere, B., Van Damme, S., & Wiersema, J. R. (2006). Components of attentional bias to threat in high trait anxiety: Facilitated engagement, impaired disengagement, and attentional avoidance. *Behaviour Research and Therapy*, *44*(12), 1757–1771. http://doi.org/10.1016/j.brat.2005.12.011
Koster, E., Verschuere, B., Crombez, G., & Van Damme, S. (2005). Time-course of attention for threatening pictures in high and low trait anxiety. *Behaviour Research and Therapy*, *43*(8), 1087–1098. http://doi.org/10.1016/j.brat.2004.08.004
Kotov, R., Gamez, W., Schmidt, F., & Watson, D. (2010). Linking “big” personality traits to anxiety, depressive, and substance use disorders: a meta-analysis. *Psychol Bull*, *136*(5),

768–821. http://doi.org/10.1037/a0020327
Kunar, M. a, Watson, D. G., Cole, L., & Cox, A. (2014). Negative emotional stimuli reduce contextual cueing but not response times in inefficient search. *Quarterly Journal of Experimental Psychology*, *67*(2), 377–393. http://doi.org/10.1080/17470218.2013.815236
Kuo, B.-C., Rao, A., Lepsien, J., & Nobre, A. C. (2009). Searching for Targets within the Spatial Layout of Visual Short-Term Memory. *Journal of Neuroscience*, *29*(25), 8032–8038. http://doi.org/10.1523/JNEUROSCI.0952-09.2009
Kvaal, K., Ulstein, I., Nordhus, I. H., & Engedal, K. (2005). The Spielberger State-Trait Anxiety Inventory (STAI): The state scale in detecting mental disorders in geriatric patients. *International Journal of Geriatric Psychiatry*, *20*(7), 629–634. http://doi.org/10.1002/gps.1330
Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg, A. (2010). Presentation and validation of the radboud faces database. *Cognition and Emotion*, *24*(8), 1377–1388. http://doi.org/10.1080/02699930903485076
Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences*, *9*(2), 75–82. http://doi.org/10.1016/j.tics.2004.12.004
Lee, L. O., & Knight, B. G. (2009). Attentional bias for threat in older adults: moderation of the positivity bias by trait anxiety and stimulus modality. *Psychology and Aging*, *24*(3), 741–747. http://doi.org/10.1037/a0016409
Lewicki, P., Hill, T., & Bizot, E. (1988). Acquisition of procedural knowledge about a pattern of stiumli that cannot be articulated. *Cognitive Psychology*, *20*, 24–37. Retrieved from FC
Lien, M. C., Ruthruff, E., Goodin, Z., & Remington, R. W. (2008). Contingent attentional capture by top-down control settings: converging evidence from event-related potentials. *J Exp Psychol Hum Percept Perform*, *34*(3), 509–530. http://doi.org/10.1037/0096-1523.34.3.509
Lien, M. C., Taylor, R., & Ruthruff, E. (2013). Capture by fear revisited: An electrophysiological investigation. *Journal of Cognitive Psychology*, *25*(7), 873–888. http://doi.org/10.1080/20445911.2013.833933
Luck, S. J., & Kappenman, E. S. (Ed.). (2011). *The Oxford handbook of event-related potential components*. Oxford University Press.
Luck, S. J., Chelazzi, L., Hillyard, S. A., & Desimone, R. (1997). Neural Mechanisms of Spatial Selective Attention in Areas V1, V2, and V4 of Macaque Visual Cortex. *Journal of Neurophysiology*, *77*(1), 24–42. http://doi.org/10.1152/jn.1997.77.1.24
Luck, S. J., & Hillyard, S. (1994). Spatial filtering during visual search: evidence from human electrophysiology. *Journal of Experimental Psychology. Human Perception and Performance*, *20*(5), 1000–14. http://doi.org/10.1037/0096-1523.20.5.1000
Ludewig, S., Ludewig, K., Geyer, M. A., Hell, D., & Vollenweider, F. X. (2002). Prepulse inhibition deficits in patients with panic disorder. *Depression and Anxiety*, *15*(2), 55–60. http://doi.org/10.1002/da.10026
Luethi, M., Meier, B., & Sandi, C. (2008). Stress effects on working memory, explicit memory, and implicit memory for neutral and emotional stimuli in healthy men. *Frontiers in Behavioral Neuroscience*, *2*(January), 5. http://doi.org/10.3389/neuro.08.005.2008
MacLeod, C., & Holmes, E. A. (2012). Cognitive Bias Modification: An Intervention Approach Worth Attending To. *American Journal of Psychiatry*, *169*(2), 118–120. JOUR. http://doi.org/10.1176/appi.ajp.2011.11111682
MacLeod, C., & Mathews, A. (2012). Cognitive Bias Modification Approaches to Anxiety. *Annual Review of Clinical Psychology*, *8*(1), 189–217. http://doi.org/10.1146/annurev-clinpsy-032511-143052

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*(1), 15–20. http://doi.org/10.1037/0021-843X.95.1.15

MacLeod, C., Rutherford, E., Campbell, L., Ebsworthy, G., & Holker, L. (2002). Selective attention and emotional vulnerability: assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, *111*(1), 107–123. http://doi.org/10.1037/0021-843X.111.1.107

MacLeod, J., Stewart, B. M., Newman, A. J., & Arnell, K. M. (2017). Do emotion-induced blindness and the attentional blink share underlying mechanisms? An event-related potential study of emotionally-arousing words. *Cognitive, Affective and Behavioral Neuroscience*, *17*(3), 592–611. http://doi.org/10.3758/s13415-017-0499-7

Macmillan, N. A. (2002). Signal detection theory. In *Stevens' handbook of experimental psychology*. (pp. 43–90).

Maidenberg, E., Chen, E., Craske, M., Bohn, P., & Bystritsky, A. (1996). Specificity of attentional bias in panic disorder and social phobia. *Journal of Anxiety Disorders*, *10*(6), 529–541. http://doi.org/10.1016/S0887-6185(96)00028-X

Maratos, F. A., Mogg, K., & Bradley, B. P. (2008). Identification of angry faces in the attentional blink. *Cognition & Emotion*, *22*(7), 1340–1352. http://doi.org/10.1080/02699930701774218

Martin, M., Williams, R. M., & Clark, D. M. (1991). Does anxiety lead to selective processing of threat-related information? *Behaviour Research and Therapy*, *29*(2), 147–160. http://doi.org/10.1016/0005-7967(91)90043-3

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Gabrieli, J. D. E., … Ochsner, K. (2004). Amygdala Responses to Emotionally Valenced Stimuli in Older and Younger Adults. *Psychological Science*, *15*(4), 259–263.

Mather, M., & Carstensen, L. L. (2005). Aging and motivated cognition: The positivity effect in attention and memory. *Trends in Cognitive Sciences*, *9*(10), 496–502. http://doi.org/10.1016/j.tics.2005.08.005

Mathews, A. (1990). Why worry? The cognitive function of anxiety. *Behaviour Research and Therapy*, *28*(6), 455–468. http://doi.org/10.1016/0005-7967(90)90132-3

Mathews, A., Fox, E., Yiend, J., & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition*, *10*(7), 823–835. http://doi.org/10.1080/13506280344000095

Mathews, A., & Macleod, C. (1985). Selective Cues Processing in Anxiety of Threat. *Behavior Research Ther*, *23*(5), 563–569. http://doi.org/10.1016/0005-7967(90)90160-K

Mathews, a, & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Psychology*, *45*, 25–50. http://doi.org/10.1146/annurev.psych.45.1.25

Mathewson, K. J., Arnell, K. M., & Mansfield, C. A. (2008). Capturing and holding attention: The impact of emotional words in rapid serial visual presentation. *Memory & Cognition*, *36*(1), 182–200. http://doi.org/10.3758/MC.36.1.182

Mathuranath, P. S., Nestor, P. J., Berrios, G. E., Rakowicz, W., & Hodges, J. R. (2000). A brief cognitive test battery to differentiate Alzheimer's disease and frontotemporal dementia. *Neurology*, *55*(11), 1613–1620. http://doi.org/10.1212/WNL.55.11.1613

Matt, G. E., Vázquez, C., & Campbell, W. K. (1992). Mood-congruent recall of affectively toned stimuli: A meta-analytic review. *Clinical Psychology Review*, *12*(2), 227–255. http://doi.org/10.1016/0272-7358(92)90116-P

McDonald, J. J., Green, J. J., Jannati, A., & Di Lollo, V. (2013). On the electrophysiological evidence for the capture of visual attention. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(3), 849–860. http://doi.org/10.1037/a0030510

Milham, M. P., Erickson, K. I., Banich, M. T., Kramer, A. F., Webb, A., Wszalek, T., & Cohen, N. J. (2002). Attentional control in the aging brain: Insights from an fMRI study of the stroop task. *Brain and Cognition*, *49*(3), 277–296. http://doi.org/10.1006/brcg.2001.1501

Miller, J., Patterson, T., & Ulrich, R. (1998). Jackknife-based method for measuring LRP onset latency differences. *Psychophysiology*, *35*(1), 99–115. http://doi.org/10.1017/S0048577298000857

Miltner, W. H. R., Krieschel, S., Hecht, H., Trippe, R., & Weiss, T. (2004). Eye Movements and Behavioral Responses to Threatening and Nonthreatening Stimuli During Visual Search in Phobic and Nonphobic Subjects. *Emotion*, *4*(4), 323–339. http://doi.org/10.1037/1528-3542.4.4.323

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy*, *36*(9), 809–848. http://doi.org/10.1016/S0005-7967(98)00063-1

Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition and Emotion*, *13*(6), 713–740. http://doi.org/10.1080/026999399379050

Mogg, K., & Bradley, B. P. (2018). Anxiety and Threat-Related Attention: Cognitive-Motivational Framework and Treatment. *Trends in Cognitive Sciences*, *22*(3), 225–240. http://doi.org/10.1016/j.tics.2018.01.001

Mogg, K., Bradley, B. P., De Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy*, *35*(4), 297–303. http://doi.org/10.1016/S0005-7967(96)00109-X

Mogg, K., Bradley, B. P., Miles, F., & Dixon, R. (2004). Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hyporthesis. *Cognition and Emotion*, *18*(5), 689–700. http://doi.org/10.1080/02699930341000158

Mogg, K., Holmes, A., Garner, M., & Bradley, B. P. (2008). Effects of threat cues on attentional shifting, disengagement and response slowing in anxious individuals. *Behaviour Research and Therapy*, *46*(5), 656–667. http://doi.org/10.1016/j.brat.2008.02.011

Mohanty, A., & Sussman, T. J. (2013). Top-down modulation of attention by emotion. *Frontiers in Human Neuroscience*, *7*. http://doi.org/10.3389/fnhum.2013.00102

Mohlman, J. (2013). Understanding late life anxiety and cognitive processes - We are rapidly gaining momentum: Introduction to the special issue. *Journal of Anxiety Disorders*, *27*(6), 547–549. http://doi.org/10.1016/j.janxdis.2013.04.008

Mohlman, J., Price, R. B., & Vietri, J. (2013). Attentional bias in older adults: Effects of generalized anxiety disorder and cognitive behavior therapy. *Journal of Anxiety Disorders*, *27*(6), 1–17. http://doi.org/10.1016/j.janxdis.2013.06.005.

Moran, T. P., & Moser, J. S. (2014). The color of anxiety: Neurobehavioral evidence for distraction by perceptually salient stimuli in anxiety. *Cognitive, Affective, & Behavioral Neuroscience*, *15*(1), 169–179. http://doi.org/10.3758/s13415-014-0314-7

Moser, J. S., Huppert, J. D., Duval, E., & Simons, R. F. (2008). Face processing biases in social anxiety: An electrophysiological study. *Biological Psychology*, *78*(1), 93–103. http://doi.org/10.1016/j.biopsycho.2008.01.005

Most, S. B., Chun, M. M., Widders, D. M., & Zald, D. H. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin & Review*, *12*(4), 654–661. http://doi.org/10.3758/BF03196754

Naveh-Benjamin, M., Hussain, Z., Guez, J., & Bar-On, M. (2003). Adult Age Differences in Episodic Memory: Further Support for an Associative-Deficit Hypothesis. *Journal of Experimental Psychology: Learning Memory and Cognition*, *29*(5), 826–837.

http://doi.org/10.1037/0278-7393.29.5.826
Newcomer, J. W., Selke, G., Melson, A. K., Hershey, T., Craft, S., Richards, K., & Alderson, A. L. (1999). Decreased memory performance in healthy humans induced by stress-level cortisol treatment. *Archives of General Psychiatry*, *56*(6), 527–533. http://doi.org/10.1001/archpsyc.56.6.527
Newell, A., & Rosenbloom, P. S. (1981). *Mechanisms of skill acquisition and the law of practice*. *Cognitive skills and their Acquisition* (Vol. 6).
Nobre, A. C. (2018). Attention. In *In: J Serences & JT Wixted. Stevens' Handbook of Experimental Psychology and Cognitive Neuroscience Volume Two: Sensation, Perception, and Attention* (4th ed., pp. 241–316). Oxford: John Wiley & Sons.
Öhman, A. (1993). Fear and anxiety as emotional phenomena: Clinical phenomenology, evolutionary perspectives, and information-processing mechanisms. In *Handbook of emotions* (pp. 511–536).
Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*(3), 466–478. http://doi.org/10.1037/0096-3445.130.3.466
Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: toward an evolved module of fear and fear learning. *Psychological Review*, *108*(3), 483–522. http://doi.org/10.1037/0033-295X.108.3.483
Olatunji, B. O., Ciesielski, B. G., Armstrong, T., & Zald, D. H. (2011). Emotional expressions and visual search efficiency: Specificity and effects of anxiety symptoms. *Emotion*, *11*(5), 1073–1079. http://doi.org/10.1037/a0021785
Palmer, K., Berger, A. K., Monastero, R., Winblad, B., Bäckman, L., & Fratiglioni, L. (2007). Predictors of progression from mild cognitive impairment to Alzheimer disease. *Neurology*, *68*(19), 1596–1602. http://doi.org/10.1212/01.wnl.0000260968.92345.3f
Palmeri, T. J. (1999). Theories of automaticity and the power law of practice. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*(2), 543–551. http://doi.org/10.1037/0278-7393.25.2.543
Patai, E. Z., Doallo, S., & Nobre, A. C. (2012). Long-term Memories Bias Sensitivity and Target Selection in Complex Scenes. *Journal of Cognitive Neuroscience*, *24*(12), 2281–2291.
Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: From a "low road" to "many roads" of evaluating biological significance. *Nature Reviews Neuroscience*. http://doi.org/10.1038/nrn2920
Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: From animal models to human behavior. *Neuron*. http://doi.org/10.1016/j.neuron.2005.09.025
Pietrzak, R. H., Maruff, P., Woodward, M., Fredrickson, J., Fredrickson, A., Krystal, J. H., … Darby, D. (2012). Mild worry symptoms predict decline in learning and memory in healthy older adults: A 2-year prospective cohort study. *American Journal of Geriatric Psychiatry*, *20*(3), 266–275. http://doi.org/10.1097/JGP.0b013e3182107e24
Pishyar, R., Harris, L. M., & Menzies, R. G. (2004). Attentional bias for words and faces in social anxiety. *Anxiety, Stress & Coping*, *17*(1), 23–36. http://doi.org/10.1080/10615800310001601458
Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*. http://doi.org/10.1016/j.clinph.2007.04.019
Pollmann, S., Zaidel, E., & Von Cramon, D. Y. (2003). The neural basis of the bilateral distribution advantage. *Experimental Brain Research*, *153*(3), 322–333.

http://doi.org/10.1007/s00221-003-1551-0
Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, 3–25. http://doi.org/10.1080/00335558008248231
Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex*, *14*(6), 619–633. http://doi.org/10.1093/cercor/bhh023
Price, R. B., Eldreth, D. A., & Mohlman, J. (2011). Deficient prefrontal attentional control in late-life generalized anxiety disorder: an fMRI investigation. *Translational Psychiatry*, *1*(10), e46. http://doi.org/10.1038/tp.2011.46
Price, R. B., Siegle, G., & Mohlman, J. (2012). Emotional stroop performance in older adults: effects of habitual worry, *20*(9), 21941169. http://doi.org/10.1097/JGP.0b013e318230340d.Emotional
Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary Suppression of Visual Processing in an RSVP Task: An Attentional Blink? *Journal of Experimental Psychology: Human Perception and Performance*, *18*(3), 849–860. http://doi.org/10.1037/0096-1523.18.3.849
Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1995). Similarity Determines the Attentional Blink. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(3), 653–662. http://doi.org/10.1037/0096-1523.21.3.653
Reardon, K. M., Kelly, J. G., & Matthews, N. (2009). Bilateral attentional advantage on elementary visual tasks. *Vision Research*, *49*(7), 691–701. http://doi.org/10.1016/j.visres.2009.01.005
Reed, A. E., & Carstensen, L. L. (2012). The theory behind the age-related positivity effect. *Frontiers in Psychology*, *3*(SEP). http://doi.org/10.3389/fpsyg.2012.00339
Reed, A. E., Chan, L., & Mikels, J. A. (2014). Meta-analysis of the age-related positivity effect: Age differences in preferences for positive over negative information. *Psychology and Aging*, *29*(1), 1–15. http://doi.org/10.1037/a0035194
Regier, D. a, Boyd, J. H., Burke, J. D., Rae, D. S., Myers, J. K., Kramer, M., … Locke, B. Z. (1988). One-month prevalence of mental disorders in the United States. Based on five Epidemiologic Catchment Area sites. *Archives of General Psychiatry*, *45*(11), 977–986. http://doi.org/10.1001/archpsyc.1988.01800350011002
Reinecke, A., Rinck, M., & Becker, E. S. (2008). How preferential is the preferential encoding of threatening stimuli?. Working memory biases in specific anxiety and the Attentional Blink. *Journal of Anxiety Disorders*, *22*(4), 655–670. http://doi.org/10.1016/j.janxdis.2007.06.004
Reutter, M., Hewig, J., Wieser, M. J., & Osinsky, R. (2017). The N2pc component reliably captures attentional bias in social anxiety. *Psychophysiology*, *54*(4), 519–527. http://doi.org/10.1111/psyp.12809
Richardson, T. M., Simning, A., He, H., & Conwell, Y. (2011). Anxiety and its correlates among older adults accessing aging services. *International Journal of Geriatric Psychiatry*, *26*(1), 31–38. http://doi.org/10.1002/gps.2474
Rinck, M., Becker, E. S., Kellermann, J., & Roth, W. T. (2003). Selective attention in anxiety: Distraction and enhancement in visual search. *Depression and Anxiety*, *18*(1), 18–28. http://doi.org/10.1002/da.10105
Rossignol, M., Philippot, P., Douilliez, C., Crommelinck, M., & Campanella, S. (2005). The perception of fearful and happy facial expression is modulated by anxiety: An event-related potential study. *Neuroscience Letters*, *377*(2), 115–120. http://doi.org/10.1016/j.neulet.2004.11.091

Ryan, J. D., Leung, G., Turk-Browne, N. B., & Hasher, L. (2007). Assessment of Age-Related Changes in Inhibition and Binding Using Eye Movement Monitoring. *Psychology and Aging*, *22*(2), 239–250. http://doi.org/10.1037/0882-7974.22.2.239

Sadeh, N., & Bredemeier, K. (2011). Individual differences at high perceptual load: The relation between trait anxiety and selective attention. *Cognition & Emotion*, *25*(4), 747–755. http://doi.org/10.1080/02699931.2010.500566

Salemink, E., Hout, M. A. Van Den, & Kindt, M. (2007). Selective attention and threat : Quick orienting versus slow disengagement and two versions of the dot probe task, *45*, 607–615. http://doi.org/10.1016/j.brat.2006.04.004

Salvato, G., Patai, E. Z., & Nobre, A. C. (2016). Preserved memory-based orienting of attention with impaired explicit memory in healthy ageing. *Cortex*, *74*, 67–78. http://doi.org/10.1016/j.cortex.2015.10.019

Sawaki, R., Geng, J. J., & Luck, S. J. (2012). A Common Neural Mechanism for Preventing and Terminating the Allocation of Attention. *Journal of Neuroscience*, *32*(31), 10725–10736. http://doi.org/10.1523/JNEUROSCI.1864-12.2012

Sawaki, R., & Luck, S. J. (2010). Capture versus suppression of attention by salient singletons: Electrophysiological evidence for an automatic attend-to-me signal. *Attention, Perception, and Psychophysics*, *72*(6), 1455–1470. http://doi.org/10.3758/APP.72.6.1455

Sawaki, R., & Luck, S. J. (2011). Active suppression of distractors that match the contents of visual working memory. *Visual Cognition*, *19*(7), 956–972. http://doi.org/10.1080/13506285.2011.603709

Schaub, R. T., & Linden, M. (2000). Anxiety and anxiety disorders in the old and very old - results from the Berlin Aging Study (BASE). *Comprehensive Psychiatry*, *41*(2), 48–54. http://doi.org/10.1016/S0010-440X(00)80008-5

Scheibe, S., & Blanchard-Fields, F. (2009). Effects of Regulating Emotions on Cognitive Performance: What Is Costly for Young Adults Is not so Costly for Older Adults. *Psychology and Aging*, *24*(1), 217–223. http://doi.org/10.3816/CLM.2009.n.003.Novel

Schmukle, S. C. (2005). Unreliability of the dot probe task. *European Journal of Personality*, *19*(7), 595–605. http://doi.org/10.1002/per.554

Schuyler, B. S., Kral, T. R. A., Jacquart, J., Burghy, C. A., Weng, H. Y., Perlman, D. M., … Davidson, R. J. (2014). Temporal dynamics of emotional responding: Amygdala recovery predicts emotional traits. *Social Cognitive and Affective Neuroscience*, *9*(2), 176–181. http://doi.org/10.1093/scan/nss131

Seiss, E., Kiss, M., & Eimer, M. (2009). Does focused endogenous attention prevent attentional capture in pop-out visual search? *Psychophysiology*, *46*(4), 703–717. http://doi.org/10.1111/j.1469-8986.2009.00827.x

Sereno, A. B., & Kosslyn, S. M. (1991). Discrimination within and between hemifields: A new constraint on theories of attention. *Neuropsychologia*, *29*(7), 659–675. http://doi.org/10.1016/0028-3932(91)90100-M

Shackman, A. J., Maxwell, J. S., McMenamin, B. W., Greischar, L. L., & Davidson, R. J. (2011). Stress Potentiates Early and Attenuates Late Stages of Visual Processing. *Journal of Neuroscience*, *31*(3), 1156–1161. http://doi.org/10.1523/JNEUROSCI.3384-10.2011

Shapiro, K. L., & Lim, A. (1989). The impact of anxiety on visual attention to central and peripheral events. *Behaviour Research and Therapy*, *27*(4), 345–351. http://doi.org/10.1016/0005-7967(89)90004-1

Shapiro, K. L., & Raymond, J. E. (1994). Temporal allocation of visual attention: Inhibition or interference? In *Inhibitory processes in attention, memory, and language* (pp. 151–188).

Shapiro, S. S., & Wilk, M. B. (1965). Biometrika Trust An Analysis of Variance Test for Normality (Complete Samples). *Source: Biometrika Biometrika Trust*, *52*(34), 591–611. http://doi.org/10.1093/biomet/52.3-4.591

Shin, L. M., & Liberzon, I. (2010). The neurocircuitry of fear, stress, and anxiety disorders. *Neuropsychopharmacology*. http://doi.org/10.1038/npp.2009.83

Siebold, A., & Donk, M. (2014). On the importance of relative salience: Comparing overt selection behavior of single versus simultaneously presented stimuli. *PLoS ONE*, *9*(6). http://doi.org/10.1371/journal.pone.0099707

Sigurjónsdóttir, Ó., Sigurardóttir, S., Björnsson, A. S., & Kristjánsson, Á. (2015). Barking up the wrong tree in attentional bias modification? Comparing the sensitivity of four tasks to attentional biases. *Journal of Behavior Therapy and Experimental Psychiatry*, *48*, 9–16. http://doi.org/10.1016/j.jbtep.2015.01.005

Sinoff, G., & Werner, P. (2003). Anxiety disorder and accompanying subjective memory loss in the elderly as a predictor of future cognitive decline. *International Journal of Geriatric Psychiatry*, *18*(10), 951–959. http://doi.org/10.1002/gps.1004

Smyth, A. C., & Shanks, D. R. (2008). Awareness in contextual cuing with extended and concurrent explicit tests. *Memory & Cognition*, *36*(2), 403–415. http://doi.org/10.3758/MC.36.2.403

Smyth, A. C., & Shanks, D. R. (2011). Aging and Implicit Learning: Explorations in Contextual Cuing. *Psychology and Aging*, *26*(1), 127–132. http://doi.org/10.1037/a0022014

Spaniol, J., Voss, A., & Grady, C. L. (2008). Aging and emotional memory: cognitive mechanisms underlying the positivity effect. *Psychology and Aging*, *23*(4), 859–872. http://doi.org/10.1037/a0014218

Spielberger, C. (1983). Manual for the State-Trait Anxiety Inventory (STAI). *Consulting Psychologists Press*, 4–26.

Srinivasan, N., & Gupta, R. (2010). Emotion-attention interactions in recognition memory for distractor faces. *Emotion (Washington, D.C.)*, *10*(2), 207–215. http://doi.org/10.1037/a0018487

Staugaard, S. R. (2009). Reliability of two versions of the dot-probe task using photographic faces. *Psychology Science Quarterly*, *51*(3), 339–350.

Stein, T., Zwickel, J., Ritter, J., Kitzmantel, M., & Schneider, W. X. (2009). The effect of fearful faces on the attentional blink is task dependent. *Psychonomic Bulletin and Review*, *16*(1), 104–109. http://doi.org/10.3758/PBR.16.1.104

Stormark, K. M., Nordby, H., & Hugdahl, K. (1995). Attentional Shifts to Emotionally Charged Cues: Behavioural and ERP Data. *Cognition and Emotion*, *9*(5), 507–523. http://doi.org/10.1080/02699939508408978

Stormer, V. S., Alvarez, G. A., & Cavanagh, P. (2014). Within-Hemifield Competition in Early Visual Areas Limits the Ability to Track Multiple Objects with Attention. *Journal of Neuroscience*, *34*(35), 11526–11533. http://doi.org/10.1523/JNEUROSCI.0980-14.2014

Stout, D. M., Shackman, A. J., & Larson, C. L. (2013). Failure to filter: anxious individuals show inefficient gating of threat from working memory. *Frontiers in Human Neuroscience*, *7*. http://doi.org/10.3389/fnhum.2013.00058

Strauss, G. P., Allen, D. N., Jorgensen, M. L., & Cramer, S. L. (2005). Test-retest reliability of standard and emotional stroop tasks: an investigation of color-word and picture-word versions. *Assessment*, *12*(3), 330–337. http://doi.org/10.1177/1073191105276375

Summerfield, J., Gitelman, D. R., Mesulam, M. M., & Nobre, A. C. (2006). Orienting Attention Based on Long-Term Memory Experience, 905–916.

http://doi.org/10.1016/j.neuron.2006.01.021
Summerfield, J., Rao, A., Garside, N., & Nobre, A. C. (2011). Biasing Perception by Spatial Long-Term Memory, *31*(42), 14952–14960. http://doi.org/10.1523/JNEUROSCI.5541-10.2011
Sussman, T. J., Jin, J., & Mohanty, A. (2016). Top-down and bottom-up factors in threat-related perception and attention in anxiety. *Biological Psychology*. http://doi.org/10.1016/j.biopsycho.2016.08.006
Szekely, A., Rajaram, S., & Mohanty, A. (2016). Context learning for threat detection. *Cognition and Emotion*, *0*(0), 1–18. http://doi.org/10.1080/02699931.2016.1237349
Tata, P. R., Leibowitz, J. A., Prunty, M. J., Cameron, M., & Pickering, A. D. (1996). Attentional bias in Obsessional Compulsive Disorder. *Behaviour Research and Therapy*, *34*(1), 53–60. http://doi.org/10.1016/0005-7967(95)00041-U
Taylor, J. M., & Whalen, P. J. (2014). Fearful, but not Angry, Expressions Diffuse Attention to Peripheral Targets in an Attentional Blink Paradigm. *Emotion*, *14*(3), 462–468. http://doi.org/10.1126/scisignal.2001449.Engineering
Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, *51*(6), 599–606. http://doi.org/10.3758/BF03211656
Theeuwes, J. (1994). Endogenous and exogenous control of visual selection. *Perception*, *23*(4), 429–440. http://doi.org/10.1068/p230429
Theeuwes, J., Belopolsky, A., & Olivers, C. N. L. (2009). Interactions between working memory, attention and eye movements. *Acta Psychologica*, *132*(2), 106–114. http://doi.org/10.1016/j.actpsy.2009.01.005
Tipper, S. P. (1991). Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society*, *29*(1), 45–47. http://doi.org/10.3758/BF03334765
Tomaszczyk, J. C., & Fernandes, M. A. (2014). Age-related differences in attentional bias for emotional faces. *Aging, Neuropsychology, and Cognition*, *21*(5), 544–559. http://doi.org/10.1080/13825585.2013.838201
Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. http://doi.org/10.1016/j.psychres.2008.05.006
Tsai, J. L., Levenson, R. W., & Carstensen, L. L. (2000). Autonomic, subjective, and expressive responses to emotional films in older and younger Chinese Americans and European Americans. *Psychology and Aging*, *15*(4), 684–693. http://doi.org/10.1037/0882-7974.15.4.684
Ulrich, R., & Miller, J. (2014). Using the jackknife-based scoring method for measuring LRP onset effects in factorial designs Using the jackknife-based scoring method for measuring LRP onset effects in factorial designs, (September 2001), 816–827.
van der Schalk, J., Hawk, S. T., Fischer, A. H., & Doosje, B. (2011). Moving Faces, Looking Places: Validation of the Amsterdam Dynamic Facial Expression Set (ADFES). *Emotion*, *11*(4), 907–920. http://doi.org/10.1037/a0023853
Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *Trends in Cognitive Sciences*. http://doi.org/10.1016/j.tics.2005.10.011
Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: an event-related fMRI study. *Neuron*, *30*(3), 829–841. http://doi.org/10.1016/S0896-6273(01)00328-2
Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2016). Effects of Attention and

Emotion on Face Processing in the Human Brain. *Neuron*, *30*(3), 829–841. JOUR. http://doi.org/10.1016/S0896-6273(01)00328-2

Vuilleumier, P., & Driver, J. (2007). Modulation of visual processing by attention and emotion: windows on causal interactions between human brain regions. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *362*(1481), 837–855. http://doi.org/10.1098/rstb.2007.2092

Wallhoff, F. (2005). The Facial Expressions and Emotions Database Homepage (FEEDTUM). Retrieved from www.mmk.ei.tum.de/~waf/fgnet/feedtum.html

Ward, E. V., Berry, C. J., & Shanks, D. R. (2013). Age effects on explicit and implicit memory. *Frontiers in Psychology*, *4*(SEP). http://doi.org/10.3389/fpsyg.2013.00639

Weierich, M. R., Treat, T. A., & Hollingworth, A. (2008). *Theories and measurement of visual attentional processing in anxiety*. *Cognition and Emotion* (Vol. 22). http://doi.org/10.1080/02699930701597601

Weymar, M., Gerdes, A. B. M., Löw, A., Alpers, G. W., & Hamm, A. O. (2013). Specific fear modulates attentional selectivity during visual search: Electrophysiological insights from the N2pc. *Psychophysiology*, *50*(2), 139–148. http://doi.org/10.1111/psyp.12008

Whalen, P. J. (1998). Fear, Vigilance, and Ambiguity: Initial Neuroimaging Studies of the Human Amygdala. *Current Directions in Psychological Science*, *7*(6), 177–188. http://doi.org/10.1111/1467-8721.ep10836912

White, L. K., Suway, J. G., Pine, D. S., Bar-Haim, Y., & Fox, N. A. (2011). Cascading effects: The influence of attention bias to threat on the interpretation of ambiguous information. *Behaviour Research and Therapy*, *49*(4), 244–251. http://doi.org/10.1016/j.brat.2011.01.004

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional stroop task and psychopathology. *Psychological Bulletin*, *120*(1), 3–24. http://doi.org/10.1037/0033-2909.120.1.3

Williams, J. M. G., Watts, F. N., MacLeod, C., & Mathews, A. (1988). *Cognitive psychology and emotional disorders*. *The Wiley series in clinical psychology*.

Wolitzky-Taylor, K. B., Castriotta, N., Lenze, E. J., Stanley, M. A., & Craske, M. G. (2010). Anxiety disorders in older adults: A comprehensive review. *Depression and Anxiety*. http://doi.org/10.1002/da.20653

Wood, S., & Kisley, M. a. (2006). The negativity bias is eliminated in older adults: age-related reduction in event-related brain potentials associated with evaluative categorization. *Psychology and Aging*, *21*(4), 815–820. http://doi.org/10.1037/0882-7974.21.4.815

Yamaguchi, M., & Harwood, S. L. (2015). Threat captures attention but does not affect learning of contextual regularities. *Cognition & Emotion*, *9931*(December), 1–8. http://doi.org/10.1080/02699931.2015.1115752

Yerkes, R. M., & Dodson, J. D. (1908). The Relation of Strength of Stimulus to Rapidity of Habit-Formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. http://doi.org/10.1037/h0073415

Yiend, J. (2010). The effects of emotion on attention: A review of attentional processing of emotional information. *Cognition and Emotion: Reviews of Current Research and Theories*, (October), 211–275. http://doi.org/10.1080/02699930903205698

Yiend, J., & Mathews, A. (2001). Anxiety and attention to threatening pictures. *The Quarterly Journal of Experimental Psychology Section A*, *54*(3), 665–681. http://doi.org/10.1080/713755991

Yochim, B. P., Mueller, A. E., & Segal, D. L. (2013). Late life anxiety is associated with decreased memory and executive functioning in community dwelling older adults. *Journal*

of Anxiety Disorders, *27*(6), 567–575. http://doi.org/10.1016/j.janxdis.2012.10.010

Zellin, M., von Mühlenen, A., Müller, H. J., & Conci, M. (2013). Statistical learning in the past modulates contextual cueing in the future. *Journal of Vision*, *13*(3), 1–14. http://doi.org/10.1167/13.3.19