Capturing Hypervigilance: Attention Biases in Elevated Trait Anxiety and Posttraumatic Stress Disorder

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I, Lorna Helen Stewart, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

The work presented in this thesis aimed to investigate attentional processing of threat in anxious individuals and its relationship to the clinical anxiety symptom of hypervigilance. Four experimental chapters report a total of nine experiments.

The first three experiments (chapters 2 and 3) describe a novel paradigm designed to measure attention bias to threat in a way which overcomes limitations of previous paradigms and which differentially measures engagement and disengagement stages of attention bias. No differences in performance were seen between high and low trait-anxious individuals. Instead a general behaviour pattern was seen in which shifting *location* of attention aids disengagement from negative *content*. Additionally, adapting the task to a training paradigm demonstrated that both engagement and disengagement processes play causative roles in emotional reactivity.

The series of experiments reported in chapter 4 investigated pre-conscious processing of (threat-related) traits in non-emotional faces. Highly trustworthy, untrustworthy and dominant faces (relative to neutral) took longer to reach awareness. Furthermore, the size of this effect was related to observers' personality traits showing that preconscious evaluation of social dimensions arises from interactions between stimulus features and observer-specific traits. British war veterans showed the same effect for trustworthy faces but altered effects for faces varying in dominance traits.

Finally, two eye-tracking experiments reported in chapter 5 captured hypervigilance in war veterans with and without PTSD. Veterans freely viewed photographs of neutral street scenes and a correlation was found between reported severity of hypervigilance and both number of saccades and duration of fixations. In a second experiment PTSD symptom related differences were seen in eye movements recorded whilst veterans walked London streets, although these did not match those see in the laboratory task.

Overall, this thesis shows that multiple stages of processing are implicated in threat biases and that such biases in attention extend to traits other than anxiety. Additionally, anxiety-related alterations in behaviour are seen even in the absence of objective threat suggesting that preferential threat processing is only part of the picture.

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Contents

List of Tables

List of Figures

Chapter 1: Literature Review

A healthy volume of work investigating the links between information processing biases and emotional responses now exists. Biased attention, interpretation, and memory biases have been demonstrated in a range of psychopathologies as well as being linked to non-clinical individual variation in emotional processing. In particular, individual differences in attention biases to threatening stimuli have been closely tied to trait anxiety as well as being thought of as a vulnerability factor in anxiety disorders. A recent body of work has suggested direct therapeutic application for this established association (Bar-Haim, 2010). However, although the co-occurrence of anxiety and attentional bias towards threat is well documented, many outstanding questions remain. To date it is unclear how attention bias modification paradigms effect change in emotional reactivity, which components of attention bias are primary in causing or maintaining anxiety, how extensively this pattern of behaviour applies across all anxiety disorders, and how such automatic non-conscious processes link to subjective conscious experience and symptomatology. Posttraumatic stress disorder (PTSD) in particular seems an obvious target for treatment which focuses on attention bias since patients report attentional change as part of the clinical symptomatology.

This chapter begins by defining some key concepts before summarising the literature on attention biases[1] and anxiety. Attention bias models of anxiety disorder will be described, followed by a review of the methods which have been used for investigating attention biases. One weakness in the literature has been the use of paradigms which are unable to differentiate between potential stages of processing at which biases occur. The next section will summarise the different stages and review evidence for threat biases existing at each. Identifying which stage biases occur at is key to improving attention bias modification procedures as a clinical intervention and the next two sections will look at these procedures and their clinical successes to date.

[1] Information processing biases in psychopathology are generally subdivided into interpretive biases, attention biases and memory biases. This review will focus upon attention biases since this is where anxiety has the greatest effect. However, these different types of biases necessarily interact and reference will be made to interpretation and memory biases at points. For a complete review of memory biases for threat in anxiety see Mitte (2008). Interpretation biases, along with memory biases, in anxiety are reviewed by Mathews & MacLeod (2005).

Finally the specific case of the anxiety disorder PTSD is discussed. The evidence for attentional biases in PTSD is mixed and will be briefly summarised before a discussion of the links between the clinically reported symptom of hypervigilance and the cognitive psychology concept of attention bias.

1.1 Definitions

1.1.1 Anxiety

Anxiety is an adaptive response to threat that is characterised by both psychological and physiological components. Whilst conceptually distinct from fear, anxiety and fear share many features and have regularly been used synonymously in the literature. Animal studies of fear have been valuable in understanding brain systems which are implicated in human anxiety responses. However, fear and anxiety are only modestly correlated and differ in a number of experiential characteristics; importantly, anxiety has been suggested to have greater future-focus whilst fear has a more present focus, and anxiety tends to be linked to diffuse threat whilst fear is generally regarded as a response to specific and immediate threat (Sylvers et al., 2011).

Individuals vary in the degree to which they experience anxious responses; this tendency, which is reasonably stable over time, is known as trait anxiety and is closely related to the personality dimension of neuroticism. Distinct from trait anxiety is the level of anxiety felt by an individual *at that moment*, known as state anxiety. Individuals who are high in trait anxiety tend to experience more occasions of elevated state anxiety, and experience increases in state anxiety in response to even moderately threatening stimuli.

Elevated trait anxiety has been commonly studied in the literature and individuals with elevated trait anxiety show the same pattern of responses as anxiety disorder patients in many cases. However, elevated trait anxiety is not an anxiety disorder, nor does it necessarily result in an anxiety disorder.

1.1.2 Anxiety Disorder

Anxiety disorder is an umbrella term for multiple forms of abnormal or inappropriate anxiety reaching a clinical level. Each type of anxiety disorder has its own characteristics and symptoms but there are many overlapping features and comorbidity between anxiety disorders is high. Most research has used the seven diagnostic categories for anxiety disorders from the Fourth Edition of the Diagnostic and Statistical Manual (DSM-IV; American Psychiatric Association, 2000), which are broadly similar to those in the Tenth Edition of the International Classification of Diseases (ICD-10; World Health Organisation, 1992). These are: Acute Stress Disorder, Agoraphobia (with or without a history of Panic Disorder), Generalized Anxiety Disorder (GAD), Obsessive-Compulsive Disorder (OCD), Panic Disorder (with or without Agoraphobia), Phobias (including Social Phobia), and Posttraumatic Stress Disorder (PTSD).

Anxiety symptoms and disorders are common with European 12 month prevalence rates of approximately 15% for anxiety disorders as a whole, and a lifetime prevalence of approximately 21% (Wittchen & Jacobi, 2005). Individual disorders are less frequent, with estimated 12 month prevalence rates ranging between 0.7% (OCD) and 7.6% (specific phobia), and lifetime prevalence rates between 0.8% (OCD) and 13.2% (specific phobia). Prevalence rates in the US are slightly higher but overall similar; National Institute of Health statistics report 12 month prevalence of anxiety disorders as a whole at approximately 18% and lifetime prevalence of approximately 29% (Kessler et al., 2005a; Kessler et al., 2005b). Sex-difference patterns vary between the different anxiety disorders but for all disorders taken together females are approximately twice as likely as males to suffer an anxiety disorder.

Anxiety disorders have considerable cost to both individuals and society. They are associated with a number of physical health problems (Rahe, 1988) and evidence suggests that in patients with comorbid anxiety disorder and a physical health problem the anxiety disorder preceded the onset of the physical condition (Sareen et al., 2006). Anxiety disorders have been associated with a significant economic burden owing to decreased work productivity and increased use of health care services, particularly primary health care (e.g. GAD: Wittchen, 2002; Panic disorder: Barbee et al., 1997;

PTSD: Schnurr & Jankowski, 1999). In 1990 the estimated annual cost of anxiety disorders in the US was $42.3 billion (Greenberg et al., 1999).

Anxiety disorders also lead to great personal suffering. Massion and colleagues (1993) report that one-third of patients with GAD in their sample were never married and 17% were separated, widowed or divorced. Additionally, suicide risk in patients with anxiety disorders has been reported to be ten times that in the general population (Khan et al., 2002). Overall, anxiety disorders markedly compromise quality of life and psychosocial functioning (Mendlowicz & Stein, 2000). Consequently, understanding the etiology and cognitive mechanisms of anxiety disorders is of great import, particularly where such understanding can be applied easily to guide therapeutic interventions.

1.1.3 Attention

Attention is the means by which our limited-capacity brains allocate processing resources; attending to some features of our environment necessitates the partial or full exclusion of other features. Cognitive scientists have traditionally divided the study of attention into focused attention (process only one input) and divided attention (process all inputs). Attention has also been used to denote concentration or distractibility, such as in studies of sustained attention (or vigilance).

In psychopathology, attentional deficits are implicated in a large number of disorders, including anxiety disorders (American Psychiatric Association, 2000). Neuropsychology approaches (e.g. review of neuropsychology findings in PTSD in Qureshi et al., 2011) have tended to assess attention in an overly-general way such that "attentional deficit" may refer to impaired performance on tasks as diverse as digit span recall (working memory), letter cancellation (also used to indicate visual-spatial dysfunction such as neglect) and continuous performance tests (used as a measure of distractibility or vigilance but also as a measure of inhibitory control). By contrast, cognitive-experimental work on attention and psychopathology has tended to focus on selective attention, the means by which certain features in the environment are selected for attentional focus.

1.2 Anxiety & Attention Biases

A link between elevated anxiety and altered attention bias for threat is now well established (for reviews see Bar-Haim et al., 2007; Cisler et al., 2009; Cisler & Koster, 2010; Ouimet et al., 2009; Yiend, 2010). A number of behavioural paradigms from the attention literature have been adapted to investigate responses to valenced stimuli (e.g. dot probe, attentional blink, visual search, Stroop) and have demonstrated that threat items are preferentially processed and, furthermore, that this effect is heightened in anxious individuals. These paradigms typically assess visual attention and measure differences in reaction times via button-press response.

Individuals with high trait anxiety, with and without elevated state anxiety, show vigilance for threat in laboratory experiments (Broadbent & Broadbent, 1988; Mogg et al., 1994), as do patients with obsessive compulsive disorder (OCD; Cohen et al., 2003; Lavy et al., 1994), posttraumatic stress disorder (PTSD; Foa et al., 1991; Kaspi et al., 1995), generalised anxiety disorder (GAD; MacLeod et al., 1986), social phobia (Mattia et al., 1993) and specific phobias (Lavy et al., 1993). This preferential processing of salient items has been termed attentional bias and has been demonstrated not only in anxious individuals but also for relevant items in substance users (Field et al., 2006), chronic pain patients (Roelofs et al., 2002), alcoholics (Bruce & Jones, 2004), smokers (Field et al., 2009), and eating disorder patients (Dobson & Dozois, 2004).

However, despite consensus that anxious individuals show *differences* in attentional processing of threat, it is still unclear at what stage these differences occur. Research to date has been interpreted as evidence that anxious individuals orientate more quickly towards threat, engage more deeply with threat items, move on more slowly from threat locations, avoid threat items, show greater interference from irrelevant distracters that are threatening, and have slowed motor responses in the presence of threat (Bar-Haim et al., 2007; Cisler et al., 2009; Cisler & Koster, 2010).

1.3 Causal Links between Anxiety and Attention Biases

More than purely maintaining anxiety, attention biases towards threat have been conceptualised as vulnerability factors for the development of later anxiety (Williams et al., 1988) and are assigned causative as well as maintenance roles in many clinical anxiety models (Eysenck & Calvo, 1992; Eysenck et al., 2007; Mathews, 1990; Mathews & Mackintosh, 1998; Mathews & MacLeod, 2002; Mogg & Bradley, 1998; Williams et al., 1988; 1997). Mathews (1990) describes attention biases and anxiety as locked in a 'vicious cycle' where each reinforces the other. Additionally, possession of an attentional bias towards threat makes individuals vulnerable to heightened emotional reactivity to subsequent stressors (MacLeod & Hagan, 1992; Wald et al., 2011b). Recent work has shown that altering attentional biases can have both protective functions (e.g. MacLeod et al., 2002) as well as therapeutic value (e.g. Amir et al., 2009a). Research on attention bias modification is reviewed later in this chapter.

Looking at this relationship from the other side, treatment of anxiety disorders through cognitive and behavioural therapeutic interventions has been shown to have an impact[2] on attentional biases. Attentional bias reduction has been demonstrated after therapy for OCD (Foa & McNally, 1986), GAD (Mathews et al., 1995; Mogg et al., 1995a), social phobia (Mattia et al., 1993), and specific phobia (Lavy et al., 1993). However, debate is still ongoing and some negative findings have also been reported; a study with PTSD patients found no change in Stroop performance for patients who had shown positive response to either cognitive-behavioural therapy or supportive psychotherapy (Devineni et al., 2004).

It is clear that anxiety and attentional biases are not only tightly interwoven but that there are also clinical implications for furthering the understanding of the processes involved in these reliably observed threat biases. One note of caution should be mentioned; common practice in the attention and anxiety literature has been to compare high with low trait anxious individuals, or to compare patient with non-patient groups. This design introduces some limitations for interpretation since it is frequently unclear

[2] Effects of therapy on attentional bias may reflect more general symptom remission rather than any direct effect of the therapy itself; depressed patients treated with antidepressant medication show reduction in negative biases also (Harmer et al., 2009).

whether group differences are the product of vulnerability or dysfunction in the high-anxious / patient groups, or due to some protective function or behaviour in the low-anxious / non-patient groups. Moreover, recent work by Elaine Fox's group has shown that allelic variation in the serotonin transporter gene is associated with attention biases towards positive and negative stimuli (Fox et al., 2009). This study suggested that individuals who have two long alleles (LL) in the promotor region of the gene show attentional bias towards positive stimuli as well as avoidance of negative, whilst individuals carrying the short allele (S or SL) do not show this potentially protective pattern of bias behaviour. Carriers of the short allele are known to be a greater risk of developing depression (Caspi et al., 2003).

1.4 Attention Bias Theories of Anxiety

A sizeable number of theories of anxiety now posit causative or maintenance roles for attention biases. Models vary in their focus on different stages of processing (orientation, engagement, disengagement, avoidance) and in whether biases are under voluntary control or accessible at a conscious level. Models also differ in how they differentiate the impact of elevated trait and state anxiety. Four main theories which assign a central role to attention bias in anxiety will be outlined. These are 1) Williams et al.'s two-stage theory (1988; 1997), 2) Cognitive motivational analysis (Mogg & Bradley, 1998), 3) Mathews & Mackintosh "Threat Evaluation System" (1998), 4) Attention Control Theory (Eysenck & Calvo, 1992; Eysenck et al., 2007). Additional models are acknowledged but are not reviewed here (Bar-Haim et al., 2007; Beck & Clark, 1997; Clark & Beck, 2010; Ouimet et al., 2009; Wells & Matthews, 1996).

1.4.1 Williams, Watts, MacLeod, and Mathews (1988; 1997)

This model, like both Mogg & Bradley's (1998) and Mathews & Mackintosh's (1998) which are outlined below, is a model of broader psychopathology than solely anxiety. The model accounts for information processing biases in both depression and anxiety, however, it makes specific predictions about anxiety and threat processing.

Williams et al. (1988; 1997) propose a two-stage model of stimulus processing which involves priming followed by elaboration. Attentional biases are postulated to act at the preconscious priming level and individual differences in trait anxiety level are hypothesised to act at this automatic (involuntary and non-conscious) stage. Preconscious processing is conceptualised as subdividing into an affective decision mechanism (ADM), which evaluates the threat level of stimuli, and a resource allocation mechanism (RAM), which allocates attention to stimuli when it is activated by high threat. Williams and colleagues suggest that state anxiety has an effect on the ADM meaning that anxious states lead to higher threat evaluations of stimuli. By contrast, trait anxiety modulates the RAM such that individuals who report elevated trait anxiety allocate attention to threat (resulting in a measurable attention bias) whilst low trait anxious individuals ignore threatening information. This latter point has been one of the main weaknesses criticised in this model. Authors (e.g. Cisler & Koster, 2010) suggest that it is implausible that low trait anxious individuals would direct attention *away from* threat even when very high levels of threat are present.

Despite such criticism Williams et al.'s model has been influential in guiding the attention and anxiety literature. The unique distinction between impacts of state and trait anxiety in particular distinguishes it from other models of anxiety. Recent neuroscientific findings have provided support for such a distinction (Bishop, 2009). It should be borne in mind however that this theoretical distinction is both difficult to study and clinically unusual since elevated trait anxiety tends to coincide with an increased tendency to experience elevated state anxiety.

1.4.2 Cognitive Motivational Analysis (Mogg & Bradley, 1998)

Mogg and Bradley (1998) also propose two theoretical systems which control attention to threat. A valence evaluation system (VES; similar to Williams et al.'s ADM) appraises threat level of incoming stimuli and outputs to a goal evaluation system (GES) which allocates processing resources including attention. In this model, unlike in Williams et al.'s model above, trait anxiety as well as state anxiety has an influence at the earlier of these two stages. High trait anxious individuals are hypothesised to evaluate stimuli as more highly threatening than would individuals with lower levels of trait anxiety.

The GES functions to interrupt current behaviour and allocate attention to the threat location when a stimulus is deemed highly threatening. This model therefore differs from that of Williams and colleagues' by predicting different responses in high and low trait anxious individuals to mildly threatening but not highly threatening stimuli. More specifically, the model contains a "vigilance-avoidance hypothesis" which posits that the relationship between threat level and attention bias is the same shape for all individuals but just shifted in individuals with elevated trait anxiety. This hypothesis suggests that all individuals show avoidance of mild threat followed by a curvilinear increasing vigilance as threat level increases. In high trait anxious individuals the shift in this relationship means that attentional responses which are characteristic of high threat are elicited by stimuli with moderate threat values.

1.4.3 Mathews' & Mackintosh's "Threat Evaluation System"

Like the two previous models, Mathews & Mackintosh (1998) also propose a "threat evaluation system" (TES; similar to the ADM and VES proposed by Williams et al. and Mogg & Bradley respectively). The output of this system, which is strengthened by state anxiety, feeds into a threat representation system. Stimuli in the TES are hypothesised to accumulate threat and must reach a certain threshold before they will be outputted to the next stage as threats. Trait anxiety lowers the threshold value which must be crossed resulting in an increased number of stimuli being outputted as threats.

Like Mogg & Bradley's cognitive-motivational account, Mathews & Mackintosh's model posits that attentional biases to valenced material result from early stimulus evaluations and *not* from preferential allocation of executive resources to attentional functions (cf Williams et al.'s model). *This* model differs from the two described previously in that it accounts for the impact of top-down effects. A "task demand" unit is postulated which acts upon the representations of evaluated stimuli in the TES to increase or decrease their activation level according to task demands or other aspects of an individual's environment. The inclusion of this unit in the model allows it to explain findings which the previous models struggle with; for example, bias reduction in the presence of real threat (Amir et al., 1996; Constans et al., 2004; Mathews & Sebastian, 1993),

1.4.4 Attention Control Theory (Eysenck et al., 2007)

Eysenck et al.'s (2007) updated Attentional Control Theory (ACT; a more detailed version of his earlier Processing Efficiency Theory, Eysenck & Calvo, 1992) postulates that anxiety disrupts three functions of the central executive, two of which are related to attentional control: inhibition and shifting. The third function in which disruption is posited, updating, is a memory function and will not be discussed further here.

These three partially interdependent central executive functions are based upon a latent variable analysis conducted by Miyake et al. (2000). Inhibition is defined as the ability to inhibit automatic responses; shifting refers to the ability to make adaptive changes in attentional control and shift between tasks depending upon demand; updating refers to the monitoring and transient storage of information. Inhibition and shifting are the functions which anxiety is proposed to have the greatest effect upon.

Eysenck and colleagues propose that anxiety weakens attentional control such that inhibitory mechanisms and control of shifting tendency are both reduced. As a result, anxiety reduces individuals' ability to resist directing attention towards task-irrelevant distracters (internal and external) as well as reducing their ability to shift focus towards task-relevant targets. Consequently, anxiety alters the balance between top-down (goal-directed attentional control) and bottom-up (stimulus-driven) attentional systems primarily because the impact of the latter is increased in anxiety. Support for this change in balance between the two systems is provided by attentional bias studies in which anxious individuals show facilitated engagement with-, and delayed disengagement from-, threat items.

ACT differs from the previous models in the extent of the emphasis placed upon top-down goal-driven attentional processes. One of the key distinctions made by the model is between performance effectiveness (quality of performance) and processing efficiency (relationship between effectiveness and the effort or resources invested). Eysenck proposes that anxiety does not always significantly alter effectiveness but, since additional effort or resources are required to maintain performance, it has a large impact upon efficiency.

1.5 Methods for Studying Attention Biases

A variety of methods have been used to measure attention biases for threat in anxious participants. The last few years have seen a growing number of tasks created for this purpose or borrowed from other areas of cognitive psychology but two experimental paradigms in particular have dominated; the emotional Stroop and the dot probe task. Most of these tasks, including the dot probe and emotional Stroop, assess the extent to which increased attention to task-irrelevant threat stimuli alter performance.

1.5.1 The Emotional Stroop Task

The emotional Stroop task is a modified version of the original colour-naming Stroop task (Stroop, 1935) in which participants are asked to colour-name emotional and neutral words presented, whilst ignoring their meaning. Slowed colour-naming of emotional words is assumed to indicate interference effects of the automatically-activated emotional content of the words. Slowed colour-naming latencies for threat words (relative to neutral words) are amplified in anxious individuals (Mathews & MacLeod, 1985; Williams et al., 1996) and are frequently interpreted as the product of irresistible attentional bias towards threat information. However, slowed colour-naming latencies in the emotional Stroop are equally well accounted for by cognitive avoidance of threat items (Deruiter & Brosschot, 1994), threat-induced slowing (Algom et al., 2004), or a combination of different types of interference (McKenna & Sharma, 2004). Consequently, although emotional Stroop effects are consistently reported in the attention bias literature, it remains unclear what mechanisms are driving these differences and so additional paradigms have been increasingly relied upon.

1.5.2 The Dot Probe Task

Unlike the emotional Stroop task, the dot probe task (MacLeod et al., 1986) does not rely on interference of emotional content with task performance. Instead, the dot probe task assesses the speeding or slowing effects of presenting emotional stimuli in the vicinity of a probe. Participants are presented with two stimuli (word stimuli in the original design; emotional faces and images related to specific anxiety concerns have since been used successfully). Following stimuli offset, a probe appears on screen in the vicinity of one of the stimuli. It is supposed that probe detection will be faster if attention is already allocated to that location. Thus, attention bias to threat is indicated when participants are faster to detect probes appearing in the vicinity of the threat stimuli relative to the neutral stimuli. Such an effect has been shown in high trait anxiety individuals (MacLeod & Mathews, 1988) as well as in clinically anxious patients (e.g. MacLeod et al., 1986).

This task has been utilised extensively in the attention bias literature. Exposure times of stimuli, probe types and stimulus types have all been varied. This work is reviewed in later sections of this chapter. Dot probe findings have frequently been interpreted as indicating a tendency to engage with valenced or salient stimuli, however it has been suggested that patterns of behaviour seen are equally well explained by a failure to disengage (Fox et al., 2001). A modified version of the dot probe task in which only one stimulus is presented on screen at a time has tried to differentiate these two processes (Fox et al., 2001; Derakshan et al., 2003 methods reported in; Derakshan et al., 2007). Trials which are validly cued (probe appears in same location as stimulus) are thought to indicate differences in engagement with neutral and valenced items whilst response latencies on invalidly cued trials (probe appears in different location to stimulus) indicate ability to disengage from stimuli. However, this methodology still suffers from limitations which are also evident in dot probe tasks in general.

Firstly, it is impossible to be certain where participants are attending at the moment when the probe appears. Several shifts of attention may have been made in the time between the stimuli appearing and the probe appearing and, consequently, the assumption that a delay on invalid trials reflects the need to shift attention from the critical stimuli is potentially flawed. Researchers have partially addressed this issue by presenting stimuli at very short durations (e.g. 17ms in Mogg & Bradley, 2002). However, saccadic eye movements take as little as 20-30ms and it is likely that covert shifts in attention may occur even more frequently.

Secondly, any assessment of disengagement is hampered by the fact that there may be differences in the degree to which participants have engaged with the stimuli initially. Engaging more fully and difficulty disengaging would both result in a slowing on invalid trials. These two stages of processing are much simpler to differentiate conceptually than practically.

Thirdly, 'disengagement' refers to disengagement from the *location* of the critical stimuli and not necessarily the content. Disengagement from content or meaning need not happen fully in order to respond to the probe presented, and is equally necessary in all trials (valid as well as invalid trials) since the participants must always shift from viewing a stimulus (stimulus presentation) to performing a motor response (probe detection or identification). Thus, disengagement delays may in fact reflect location-shifting delays and may not tell us anything about individuals' ability to process negative information.

Finally, in all versions of the dot probe task, participants respond to a neutral target (the probe) and the valenced cue is task-irrelevant. It seems possible at least that the effects of anxiety may be different if the probe were task-relevant.

1.5.3 Posner's Adapted Spatial Cueing Task

In Posner's original cueing task (Posner et al., 1980) cues are presented on screen followed by a target in one of two locations (valid or invalidly cued). The majority of trials are validly cued and performance in these trials is faster than neutrally cued trials demonstrating the tendency to engage with the cued location. Similarly response latencies to invalid cues are generally slower than to neutral cues, indicating the time cost of disengaging attention from the opposite location. This paradigm has been adapted to include emotional stimuli by manipulating the valence of the cue. Speeded reactions to valenced compared to neutral items on valid and invalid trials are interpreted as evidence for facilitated engagement and disengagement respectively. Both facilitated engagement with, and impaired disengagement from, threat have been shown in anxious populations with this paradigm (Cisler et al., 2009).

1.5.4 Visual Search

Visual search tasks require participants to detect a target stimulus in an array of distracter stimuli. This type of task have been extensively used to investigate attentional priority effects and, more recently, valenced stimuli have been incorporated to enable investigation of attentional prioritisation of emotion (Ohman et al., 2001; Rinck et al., 2003). Facilitated engagement is deduced when *threat targets* among neutral distracters are found more quickly than neutral targets among neutral distracters. Similarly, impaired disengagement is revealed when neutral targets amongst *threatening distracters* are identified more *slowly* than neutral targets amongst neutral distracters. Studies of anxious individuals have provided evidence for exaggeration of both of these effects in a variety of anxiety populations (see Cisler et al., 2009 for a review).

1.5.5 Novel Methods for Assessing Attention Bias

Posner tasks and visual search paradigms have provided evidence for anxiety-related differences in both engagement and disengagement processes with some studies demonstrating differences in both bias stages within one experiment (Rinck et al., 2003, experiment 2; Rinck et al., 2005, experiment 2 and 3). Findings from the emotional Stroop and dot probe have similarly provided evidence of effects of anxiety on both engagement and disengagement. However, they have sometimes yielded inconsistent findings (e.g. Mogg et al., 2000a but c.f.; Egloff & Hock, 2003; Posner, 1980; Brosschot et al., 1999) but the reasons for these discrepancies have been unclear. Brosschot and colleagues (1999) suggested that the dot probe task measures attentional allocation at a later stage of processing than the emotional Stroop task. Alternatively, it has been suggested that the dot probe task reflects a 'spotlight' of attention which scans the visual field whilst the emotional Stroop reflects a stationary spotlight in which the information must be deciphered (Mogg et al., 2000a).

Alternative, less-frequently utilised paradigms help to elucidate these ambiguities. Tasks demonstrating anxiety-related differences in recent years have included the attentional blink (Fox et al., 2005), the anti-saccade task (Ansari et al., 2008), and binocular rivalry (Gray et al., 2009; Nagamine et al., 2007). Electrophysiological (Bar-Haim et al., 2005; Fox et al., 2007a; 2007b) and eye-tracking measures (Ansari & Derakshan, 2008; Derakshan & Koster, 2010) have also shown differences in attention to valenced stimuli in anxious individuals.

Some of these tasks and findings will be discussed in more detail in later chapters. It is important to note that all these tasks rely upon comparing neutral and emotional stimuli to investigate (anxiety) group differences. Visual search and Posner tasks measure multiple components of attentional bias but do not lend themselves easily to modification to training tasks like the dot probe task or are subject to some of the same limitations as the dot probe task.

1.6 Stages of Attention Bias

The models outlined above generally converge on the idea that there are evaluation and attentional allocation stages in threat detection. However, attention is not a unitary construct (Posner, 1980) and there is ongoing debate about the sub-stages of attentional bias. Four conceptually distinct phases which are commonly referred to in the literature are outlined below; 1) *orientation* towards a stimulus, 2) *engagement* with the stimulus, 3) *disengagement* of attention from the stimulus, 4) *avoidance* of attentional engagement with the stimulus. The bulk of the literature on attentional bias and anxiety has tended to focus upon engagement and disengagement and there has been some debate about whether anxiety-related differences in attentional bias are primarily difficulties in engagement or disengagement. Orientation and avoidance mechanisms have received less attention. Each of these processes is difficult to isolate and consequently studies have often been interpreted as evidence for a difference at more than one stage of processing.

1.6.1 Orientation

Physiological reactivity to biologically relevant threat-stimuli does not require conscious awareness or appraisal and neuroimaging studies show that threat prioritisation at a pre-conscious stage of processing is supported by neural circuitry (see Ohman, 2005 for a review). Such early threat processing aids speeded (covert) orientation to threat. Evidence from paradigms utilising subliminal exposures for stimuli (brief exposures <30ms as well as backwards masking) suggests not only that differences in pre-conscious orientation towards threat exist in a range of anxiety disorders (e.g. Mogg & Bradley, 2002; Bradley et al., 1995; Harvey et al., 1996) but also that orientation towards threat predicts emotional reactivity to a subsequent stressor (MacLeod & Hagan, 1992; Van Den Hout et al., 1995).

1.6.2 Engagement

Preferential threat-processing seen in anxious individuals using masked versions of the dot probe task (e.g. Bradley et al., 1997a; Mogg & Bradley, 2002; Mogg et al., 1995b) and emotional Stroop tasks (e.g. Bradley et al., 1995; MacLeod & Rutherford, 1992; Mogg et al., 1993) has been hypothesised to reflect increased engagement with threat by some authors (e.g. Cisler & Koster, 2010) and not facilitated orientation to threat as suggested by others (e.g. Ouimet et al., 2009).

Visual search studies have also demonstrated facilitated engagement in anxious individuals (Rinck et al., 2003, experiment 2; Rinck et al., 2005, experiments 2 and 3) and Koster and colleagues (2006) found that anxious individuals show facilitated attention towards high levels of threat at short presentation times of 100ms (but not mild threat and not at long at longer stimulus durations). Additionally, Mathews, Fox, Yiend & Calder (2003) present a modified gaze-cuing task which potentially[3] demonstrates that high trait anxious individuals are more likely to attend to a location indicated by a fearful expression (rather than to the location of the fearful expression itself).

[3] Fox (2004) discusses the limitations of this study.

However, some studies have failed to find any evidence for facilitated engagement with threat amongst anxious individuals in the Posner Paradigm (e.g. Amir et al., 2003), attentional probe tasks (Yiend & Mathews, 2001) and in visual search (Pineles et al., 2007; 2009; Rinck et al., 2003, experiment 1; Rinck et al., 2005, experiment 1). Moreover, an initial orienting away from relevant stimuli has been found in social phobics (Chen et al., 2002). Such findings do not fit with the proposal of a general speeded orienting to-, or engagement with-, threat in anxious individuals. Moreover, all individuals, regardless of anxiety level, show facilitated detection of angry compared to happy facial expressions (Fox et al., 2000). Hence, Cisler & Koster (2010) suggest that facilitated attention towards threat is detected in anxious individuals only when highly threatening stimuli are presented at short durations.

1.6.3 Disengagement

Fox, Russo, Bowles & Dutton (2001) argue that attentional biases primarily reflect a difficulty in *disengaging from* threat stimuli for anxious individuals and not facilitated engagement. Fox and colleagues report a modified version of the dot probe task which they adapted to address the limitation that both the original dot probe and the emotional Stroop tasks are unable to distinguish whether threat stimuli attract attention initially or whether attention is captured and remains overly long in the vicinity of the threat stimuli. By presenting only one stimulus on screen at a time (threatening, neutral or positive) and comparing response times in valid (probe appears in same location as stimuli) and invalid (probe appears in opposite location to stimuli) trials they were able to compare engagement and disengagement processes. High state-anxious participants were slower to respond to a probe on invalid trials when the preceding stimulus was an angry face than when it was a neutral or positive face. Additionally, angry faces on valid trials did not result in faster response times than neutral or positive faces. As discussed previously, these findings are explicable by a delayed disengagement account but not by facilitated engagement with threat.

Support for a delayed disengagement account of threat bias in anxiety has also been shown in other forms of modified probe detection tasks (Georgiou et al., 2005; Salemink et al., 2007) as well as in a visual search paradigm in Vietnam veterans with and without PTSD (Pineles et al., 2007). Several research groups have posited that delayed disengagement from threat stimuli may be the primary attentional difference between high and low anxious individuals (Derryberry & Reed, 2002; Fox et al., 2001; 2002; Yiend & Mathews, 2001).

Most of the attention models of anxiety outlined above do not make predictions specifically about disengagement processes. However, Attention Control Theory (Eysenck et al., 2007) posits that anxiety weakens top-down regulatory control and consequently it could be inferred that anxiety should lead to difficulties disengaging from threat stimuli.

1.6.4 Avoidance

In a series of studies conducted in Yair Bar-Haim's laboratory, avoidance of threat-stimuli has been shown to be related to PTSD symptomatology (Bar-Haim et al., 2010; Wald et al., 2011a; 2011b) and multiple studies of social anxiety have shown avoidance of relevant stimuli (e.g. Chen et al., 2002; Horley et al., 2003; Mansell et al., 1999; Moukheiber et al., 2010). Moreover, avoidance potentially plays a significant role in maintaining anxiety disorders; Price et al. (2011) report that social phobia patients with avoidant biases report higher symptom levels after cognitive behavioural therapy than do patients with vigilant biases.

These studies have all displayed stimuli for longer durations (500ms and above) and thus allow for the possibility that anxiety disorder patients also show differences at earlier stages of attentional processing as well as in later avoidance behaviours. Indeed, evidence is growing that vigilance is frequently followed by subsequent avoidance in some clinical anxiety disorders and a "vigilance-avoidance" (VA) pattern of processing is endorsed by many researchers (e.g. Mathews, 1990; Mogg et al., 1989; Mogg & Bradley, 1998). This VA pattern is characterised by initially speeded attention towards threat and later avoidance of threat. Fox (2004) suggests that specific phobias may be characterised by a VA pattern of attention to threat, whilst general anxiety disorders are instead characterised by vigilance-maintenance (i.e. delayed disengagement). Indeed, research from other branches of psychology has argued for subclasses of anxiety disorders (e.g. Clark & Watson, 2006; Watson, 2009) and it is possible that these subclasses would show differing patterns of bias for threat information[4].

Beyond clinical anxiety, Derakshan, Eysenck & Myers (2007) suggest that VA is characteristic of the repressive coping style of 'repressors' (individuals reporting low anxiety and high defensiveness) when they encounter self-relevant threat. Moreover, they propose that such avoidance is instrumental in producing *low* levels of anxiety and as such can be considered a protective behaviour. Derakshan et al. propose that the vigilant stage occurs rapidly and is automatic and non-conscious whilst the avoidant stage involves controlled and strategic processes and may reflect possible coping and emotion regulation strategies. It is as yet unclear how this avoidance strategy could be related to low anxiety in some individuals (e.g. repressors in this account) but to phobia in other individuals.

1.7 Looking at Causality: Attention Bias Modification

Although the extensive evidence for associations between attention biases and anxiety is compatible with models of these disorders, testing the prediction that such biases play a causal role requires a different approach. Demonstration of association between biases and emotional reactivity does not rule out the possibility that both are the product of some other process or, indeed, that anxiety causes processing biases. Variants of the dot probe task, in which contingencies are set up between stimulus valence and probe location, have been used as attention bias modification (ABM) procedures in order to investigate such causal links between biases in processing and emotional reactivity.

In their seminal study, MacLeod et al. (2002) trained two groups of mid-anxious participants to differentially attend to threatening or neutral stimuli. One group ('attend threat') performed a dot probe task where probes always appeared in the vicinity of the

[4] Prioritisation of threat information has been used to explain some of the core features of anxiety, such as hypervigilance and heightened startle reflex. Evidence for difficulty in disengaging from threat in anxious individuals could potentially explain a different set of features and have clinical implications such as increased rumination and worry (Fox et al., 2001). Fox (2004) suggests that delayed disengagement from threat may result in the worry (Mathews, 1990) and memory bias for negative material (for reviews see MacLeod, 1999; Mogg et al., 1987) that are commonly seen in clinically anxious individuals. Verkuil, Brosschot, Putman, and Thayer (2009) reported that slowest disengagement from threat was evident in a group of participants who were high in trait worry *as well as* trait anxiety.

threatening word (one threat and one neutral word were presented in all trials), whilst the other group ('avoid threat') performed a task where probes always appeared in the vicinity of the neutral word. After 576 training trials the 'attend threat' group showed biases towards threatening stimuli in the same direction as anxious individuals. Critically, bias modification did not alter state anxiety levels but instead individuals who were trained to attend to threatening stimuli showed elevated emotional reactivity (an increased *change* in state anxiety from pre- to post-task) to a subsequent stressor (insolvable anagrams in this study). This study was the first to demonstrate that altering attention biases truly does alter the level of anxious response to a stressful event. Dot probe bias modification has also been used to induce positive attention bias (Wadlinger & Isaacowitz, 2008) and subsequently reduce dwell-time of fixations to negative stimuli.

See, MacLeod & Bridle (2009) showed that ABM can attenuate anxiety response to real-life stressors. Participants who were trained to attend away from negative words in daily sessions over the course of two weeks showed reduced anxiety response to a major life event (enrolling in university in a foreign country). Clarke et al. (2008) also demonstrated a relationship between ABM and emotional reactivity. However, they posit that individual differences in tendency to acquire threat bias predict an individual's tendency to develop threat bias and therefore portend their subsequent emotional response to a life stressor (university exams). This explanation is distinct from that offered by other authors who have suggested that attentional bias modification procedures work to directly alter attention biases in a lasting way (see patient literature below).

Indeed, the mechanisms by which ABM predicts differences in emotional reactivity are largely unknown and have been a source of contention. It has been suggested that the efficacy of ABM could be explained by such factors as manipulation of mood (Standage et al., 2010) or attentional control improvement (Eldar & Bar-Haim, 2010). Moreover, it is as yet unclear at which stage of processing ABM acts. Only two published studies have shown an anxiety-response impact of attentional training using a methodology not related to dot probe tasks (Dandeneau et al., 2007; Hirsch et al., 2011). The attentional bias modification literature therefore suffers from all the weaknesses associated with the dot-probe task and it is unclear what attentional components (orientation, engagement, disengagement, or avoidance) are being altered by ABM or, moreover, which of these must necessarily be modified to enact a change in emotional reactivity. In a large proportion of ABM studies it is essentially avoidance patterns of attention which are being trained. It is as yet unclear how the reductions in anxiety response which ABM begets by training avoidance fit with literature which links avoidance behaviour to greater anxiety symptomatology (e.g. Chen et al., 2002; Wald et al., 2011a; Wald et al., 2011b). Recent work has attempted to address some of these gaps in the literature. Hirsch et al. (2011) have shown effects on worry of modifying engagement but not disengagement biases whilst, conflictingly, ABM has been shown to alter early but not late components of attentional bias (Koster et al., 2010).

Dependent measures of ‘emotional reactivity’ in non-patient ABM studies have not varied a huge amount and have been mostly confined to state anxiety or mood changes. Exceptions to this generalisation demonstrated a significant impact of attentional bias training upon worry tendencies (Hayes et al., 2010; Krebs et al., 2010) and cortisol changes, self-esteem, and work performance (Dandeneau et al., 2007). Researchers have also investigated the impact of ABM upon implicit associations, behavioural approach and skin conductance response in spider-fear (Van Bockstaele et al., 2011), although no effects of spider-focused ABM were found on these measures. There is clearly a need for investigation into how ABM might alter more clinically-relevant responses to stressors such as intrusive imagery (analogous to PTSD), checking behaviours (OCD), avoidance behaviours (phobia, PTSD), or perhaps tendency to stay indoors (agoraphobia). Paradigms which measure the effect of ABM upon these outcomes in non-patient groups have an advantage over patient studies in terms of furthering the testing of cognitive models since temporarily increasing bias towards threat is likely more ethically acceptable in non-patient than patient groups.

1.8 Returning to the Clinic: ABM as Treatment

Whilst the laboratory studies of attentional bias modification provide evidence strongly suggestive of a causal link between biases and emotional reactivity and seem to suggest therapeutic applications, they do not in themselves demonstrate that bias modification could be sufficient to alter clinical anxiety responses. It is possible that clinical anxiety differs qualitatively and not just quantitatively from elevated trait anxiety. Moreover, ABM as prevention of later reactivity may require very different techniques to altering the established maintaining role of attention bias in patients.

Despite that, there is a growing body of work showing that only a few sessions of bias-reduction training improves symptomatology in patients across a range of anxiety disorders (e.g. pathological worry: Hazen et al., 2009; social phobia: Amir et al., 2008; Klumpp & Amir, 2010; Li et al., 2008; OCD: Amir et al., 2009b; GAD: Amir et al., 2009a; Schmidt et al., 2009; spider phobia: Reese et al., 2010). Conversely, attentional biases have been found to disappear following anxiety treatment in spider phobia (Lavy et al., 1993), social phobia (Mattia et al., 1993), OCD (Foa & McNally, 1986) and GAD (Mathews et al., 1995). The frequency, duration, and number of ABM sessions required for improvement in clinical symptoms has varied between studies and it remains to be seen how specific stimuli need to be, either to disorders or individuals, and whether ABM has effects in all patients and all disorders. Work by Colin MacLeod's (2007) group suggests that ABM could be administered online which provides substantial hope for patients who traditionally have difficulty accessing treatment clinics (e.g. agoraphobics). Similar training paradigms have also been shown to be effective in disorders which are commonly comorbid with anxiety (pain: Baert et al., 2010; depression: Dehghani et al., 2004; alcoholics: Fadardi & Cox, 2009; Schoenmakers et al., 2010; smokers: Field et al., 2009).

1.9 Posttraumatic Stress Disorder

Posttraumatic stress disorder (PTSD) is an anxiety disorder which can develop following a traumatic life event. The diagnostic criteria (American Psychiatric Association, 2000) require that 1) the individual has experienced or witnessed an event which meets specific criteria as a trauma, 2) that event is re-experienced (as thoughts, flashbacks, dreams or intense physiological reactivity to reminders of the event), 3) the individual experiences three or more avoidance symptoms (avoiding reminders or thoughts, inability to remember details or the trauma, diminished interest in activities, feelings of detachment, restricted range of affect, sense of foreshortened future), 4) the individual reports two or more hyperarousal symptoms (sleeplessness, irritability, inability to concentrate, exaggerated startle reflex, hypervigilance), 5) these symptoms continue for more than one month (acute stress disorder is diagnosed if very similar symptoms are present but for less than 4 weeks), and 6) the symptoms cause impairment or distress.

Amongst anxiety disorders PTSD is by no means uncommon. Lifetime prevalence in US civilians has been estimated at 7.8% (Kessler et al., 1995) and estimates for 12-month prevalence range between 1.3% (Australia; Creamer et al., 2001) and 3.6% (USA; Narrow et al., 2002). Current UK estimates are 3% of the population (National Centre for Social Research, 2009).

Amongst military populations the picture is less clear. US lifetime prevalence estimates have ranged from approximately 6% to 31% and point-prevalence rates from approximately 2% to 17% (Richardson et al., 2010). Prevalence rates amongst British veterans are generally lower; the largest study of UK veterans to date reported current rates of approximately 4% (Hotopf et al., 2006).

As with anxiety disorders more generally, PTSD is associated with decreased work productivity and increased use of healthcare facilities (Schnurr & Jankowski, 1999). Amongst PTSD patients relationship difficulties and domestic violence are not uncommon (Jordan et al., 1992) and being unemployed, having compromised physical health and diminished well-being are all more likely amongst Vietnam veterans with PTSD than those without (Zatzick et al., 1997).

1.10 Attentional Disturbance in PTSD

Hypervigilance is part of the symptomatology of both acute stress disorder and PTSD (American Psychiatric Association, 2000), was previously a symptom in GAD (American Psychiatric Association, 1980) and is commonly reported by patients. It is variously described in different clinical assessments but always involves being watchful for general threat; for example, ‘being overly alert (for example, checking to see who is around you, being uncomfortable with your back to a door, etc.)’ (Post-traumatic Stress Diagnostic Scale; McCarthy, 2008), ‘I felt watchful and on-guard’ (Impact of Event

Scale; Horowitz et al., 1979), 'being "super alert" or watchful or on guard' (Blanchard et al., 1996). Interview assessments for hypervigilance make reference to the reaction being out of proportion to the threat that is present but do not specify a need for any threat to be present; being 'watchful or on guard *even when there was no reason* to be' (my italics; Structured Clinical Interview for DSM-IV; First et al., 2002) or 'especially alert or watchful, *even when there was no real need* to be' (my italics; Clinician Administered PTSD Scale; Blake et al., 1995). In trauma survivors the presence of the hyperarousal cluster of symptoms (which includes hypervigilance[5]) not only predicts the onset of other symptoms (Marshall et al., 2006) but is also inversely related to overall symptom improvement (Schell et al., 2004).

Impairments have been shown amongst PTSD patients on a variety of attention tasks involving non-valenced stimuli (Qureshi et al., 2011). Impairments span sustained, selective, and divided attention (Jenkins et al., 2000; Koso & Hansen, 2006; Vasterling et al., 1998; Vasterling et al., 2002). There is also extensive evidence that PTSD patients show biased attention towards threat in a range of paradigms (dot probe: Bryant & Harvey, 1997; Harvey et al., 1996; emotional Stroop: Foa et al., 1991; Kaspi et al., 1995; attentional blink: Amir et al., 2009c)[6]. However, some studies have failed to find such an effect (e.g. Bremner et al., 2004; McNally et al., 1996; Shin et al., 2001) and a review of published literature as well as unpublished dissertation work by Kimble and colleagues (2009) concluded that the presence of an emotional Stroop effect for trauma-specific stimuli in PTSD is grossly over-estimated and the generally-accepted presence of this phenomenon is premature.

Recent work in non-patients has shown that attention biases *during* trauma predict later PTSD symptoms (Wald et al., 2011b) and that these attention bias differences are not present before exposure to trauma (Wald et al., 2011a). Interestingly, the greater the

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[5] The other symptoms in the hyperarousal cluster are sleeplessness, irritability, difficulty concentrating, and exaggerated startle response (American Psychiatric Association, 2000).

[6] Studies of attentional bias in PTSD have generally included a trauma-exposed control group but not another anxiety disorder group so it is uncertain whether these effects are specific to PTSD or are more general anxiety effects as reported previously (Buckley et al., 2000). Additionally there is some disagreement in the literature as to whether PTSD patients show *trauma-specific* threat-processing differences (e.g. Bryant & Harvey, 1997; Foa et al., 1991; Kaspi et al., 1995; Thrasher et al., 1994) or more general threat biases (e.g. Litz et al., 1996). Note that these two contentions are not necessarily connected; if the attention biases seen in PTSD are generalised beyond trauma reminders this does not necessarily indicate that they are not PTSD-specific.

avoidance of threat stimuli in a dot probe task, the greater the number of PTSD symptoms which were displayed in trauma-exposed individuals. A previous study by the same group of researchers had also found that degree of avoidance of threat-stimuli was correlated with distress during the trauma period for individuals living within rocket range during the outbreak of the Israeli-Gaza war in 2008 (Bar-Haim et al., 2010).

In addition to these studies suggesting a link between attentional vulnerabilities and subsequent trauma response, Verwoerd et al (2008) found that greater self-reported attentional control was associated with reduced emotional reactivity to a trauma-analogue film, as assessed by the Impact of Events Scale (Horowitz et al., 1979) and the number of intrusions of the film over the subsequent fours days. However, caution should be urged when interpreting this finding since self-reported attentional control may not be related to actual attentional control and, furthermore, the link to threat biases is unconfirmed.

To my knowledge no studies have attempted to modify attentional biases in PTSD patients, nor have any studies reported attentional bias change as a result of therapeutic interventions for PTSD. Additionally, no published studies have looked at the effect of modifying attentional biases upon subsequent trauma response or upon behaviours which might be considered analogous to PTSD symptoms. It therefore remains to be seen whether attentional biases can be considered to play a causative role in PTSD in the same way that they are posited to do so in other anxiety disorders.

Many studies imply a commonality between attentional bias (as defined by the cognitive psychology literature) and hypervigilance (the clinical symptom) even if they do not directly equate them (e.g. Dalgleish et al., 2001; Vythilingam et al., 2007). Consequently, hypervigilance, as it has been described in most of the cognitive psychology literature, refers to an increased tendency to attend to salient stimuli or features (in the case of anxiety these are threat-related). This might mean attending quicker (facilitated orientation to- or engagement with- threat) or for longer (delayed disengagement from threat), or having a lowered threshold for which stimuli are categorised as threatening. Pineles et al. (2007; 2009) suggest that facilitated engagement with threat may be related to hypervigilance whilst delayed disengagement may be related to concentration difficulties, the ability to complete the task effectively and on time, or to the uncontrollability of intrusive memories in PTSD. Thus, attentional bias to threat is content-dependent whilst clinical hypervigilance, as previously described, refers to a content-independent behaviour.

It is tempting to consider hypervigilance as analogous to attention bias to threat since hypervigilance is the first symptom of PTSD to develop in delayed-onset PTSD (Andrews et al., 2009), just like attention biases are posited to foreshadow and play a causative role in anxiety disorders. However, hypervigilance as clinically described is multi-faceted and there are other potentially analogous concepts from cognitive psychology by which it could be explained; reduced attentional control generally or inhibitory control specifically; increased general distractibility; heightened sensitivity to unpredictable cues; difficulties in sustained and/or focussed attentional processes, or in switching between these modes of operation; interpretational bias (such that not only are mildly threatening stimuli elevated in their saliency but even neutral stimuli take on potential threat meaning); strategic or consciously employed behaviour which does not have an automatic, non-conscious correlate; heightened reactivity of the sympathetic system or increased sensitivity to sympathetic reactions.

1.11 Information Processing Models of PTSD

In addition to information processing models of anxiety, specific information processing models of PTSD have been proposed (Brewin et al., 1996; 2010; Chemtob et al., 1988; Ehlers & Clark, 2000; Foa et al., 1989; Litz & Keane, 1989; for reviews see: Brewin & Holmes, 2003; Buckley et al., 2000). Most of these theories place memory phenomena in PTSD at the centre and do not make specific predictions about attentional processes. Some of the models (Brewin et al., 1996; Ehlers & Clark, 2000) make predictions about information processing peri-traumatically which may reflect pre-existing vulnerabilities but do not discuss whether such patterns of processing continue after trauma and help to maintain PTSD. One exception to this is Chemtob et al.'s Cognitive Action Theory of combat-PTSD (Chemtob et al., 1988) which does partially address biases in attentional processes in PTSD. However, this is not the focus of the theory and, as a result, attention biases in PTSD are perhaps best understood in the framework of attention models of more general anxiety as outlined above.

1.12 Summary

Attentional bias to threat has been extensively researched in elevated trait anxiety as well as anxiety disorders and there is now general consensus that attentional biases play both causative and maintenance roles in anxiety. A number of cognitive theories of anxiety place attentional bias to threat centrally and a range of paradigms have been developed or adapted for investigating these behaviours. There is a growing literature showing that adapting these paradigms to become training procedures for attention has therapeutic value for patients. However, it is still unclear which stages of attentional processing are altered in anxiety and, consequently, where bias modification techniques should be focussed for maximal therapeutic efficacy.

In post-traumatic stress disorder, like in other anxiety disorders, there is evidence for biased attentional processing of threat information. Moreover, recent work shows that the presence of these biases predicts later PTSD symptomatology. The symptom 'hypervigilance' is often viewed as the clinical manifestation of attentional bias towards threat and it both arrives first and is part of the (hyperarousal) cluster of symptoms which predicts the severity of the subsequent disorder. However, patient reports of hypervigilance differ fundamentally from the cognitive psychology concept of attentional bias. Furthering understanding of this discrepancy is crucial for both cognitive models of PTSD and clinical work which stems from these.

1.13 Aims and Objectives

This thesis takes as its starting point the extensive cognitive psychology literature and theories of attentional bias in anxiety. I began by designing a new attentional bias paradigm to differentially evaluate engagement and disengagement within one task (chapter 2, experiment 1 and, chapter 3, replication and extension). Moreover, this task lent itself to adaptation to an attentional bias modification procedure (chapter 2, experiment 2) and so aimed to allow investigation of the independent contribution of engagement and disengagement to emotional reactivity. Chapter 2, experiment 1 and chapter 3 report differences on task performance between high- and low- trait anxious individuals. Chapter 2, experiment 2 reports a pilot study investigating the impact of differentially manipulating engagement and disengagement biases upon the development of intrusive memories after a trauma-analogue stressor.

Chapter 4 reports a series of experiments which investigate non-conscious vigilance for emotionally neutral stimuli which still have potential threat value (untrustworthy and dominant faces). The final experiment in this series reports PTSD patients' performance.

Following from this cognitive psychology literature-driven approach I subsequently returned to reports from PTSD patients about experiences of hypervigilance and attempted to capture this experience using quantitative behavioural measures (eye-tracking, chapter 5).

At all times I have tried to give equal weight to clinical and cognitive psychology ideas and approaches. Consequently, I hope that this thesis truly bridges the domains of cognitive and clinical psychology in a way that is meaningful to both disciplines.

Chapter 2: Attention bias in anxiety: A novel task for differentiating engagement and disengagement processes.

A role for attention biases in both maintaining and causing anxiety disorders has received extensive support in the literature. However, the bulk of this supporting evidence relies on the use of just two experimental paradigms; the emotional Stroop (Stroop, 1935) and variants of the dot probe task developed by MacLeod et al. (1986). Whilst these paradigms have contributed meaningfully to our understanding of attention biases they are limited in a number of ways.

First, they do not comprehensively distinguish between engagement and disengagement processes of attentional bias. This makes it hard to differentiate between competing accounts of the fundamental components of attentional biases which underlie anxiety. Second, in the dot probe task, locus of attention prior to the probe appearing is assumed and not measured or controlled. This limitation means that avoidance and facilitated disengagement are confounded, as are vigilance and impaired disengagement. The consequence of these confounds is that avoidance and vigilance have sometimes been viewed as mutually exclusive processes, although there is evidence that anxious individuals may actually show altered behaviour in both these processes (Pflugshaupt et al., 2005; Wieser et al., 2009a). Third, *locational* disengagement in the dot probe task has been assumed to be a proxy for disengagement from the *content* of stimuli. This assumption seems intuitively valid but also conflicts with evidence from the emotional Stroop paradigm of interference effects of threat stimuli in anxious individuals. Given these restrictions it is clear that a new paradigm is needed which addresses such difficulties.

Recent work in Colin MacLeod's laboratory has attempted to control for these limitations. In order to address the dilemma of locating participants' attention immediately prior to onset of the stimuli, a "decoupled" emotional Stroop task was utilised in which each trial consisted of two responses in sequence (Hart, 2005; Sadler, 2006). Whilst the conventional emotional Stroop task presents stimulus content and colour simultaneously, the decoupled emotional Stroop presents these sequentially. Participants are asked to make two judgements in quick succession (naming of ink-colour and a lexical decision), and the generation of the first response prompts provision of the second source of information. On trials that assess *engagement* with threat colour information (without meaning) is presented initially. Participants make a colour-naming response to a display of Xs; this response initiates the presentation of meaning information (Xs are replaced by a word) to which they must then make a lexical decision. Similarly, on trials that assess *disengagement from threat,* meaning information (a word) is presented initially in monochrome. A lexical decision by the participant to this stimulus prompts the presentation of colour and the participant must then name the colour. Calculating the time between the two responses in a trial gives measures of engagement and disengagement respectively.

Using this methodology Hart (2005) found that high trait anxious individuals showed facilitated engagement with threat unlike low trait anxious individuals. She did not find any evidence of speeded or delayed disengagement in high trait anxious individuals. Sadler (2006) further modified the decoupled emotional Stoop so that stimuli could be presented in either of two locations and thus some trials required participants to shift the location of their attention, whilst others did not. The findings, like that of Hart, showed that anxiety-linked attentional bias is characterised by facilitated engagement with threatening material, but not by impaired disengagement.

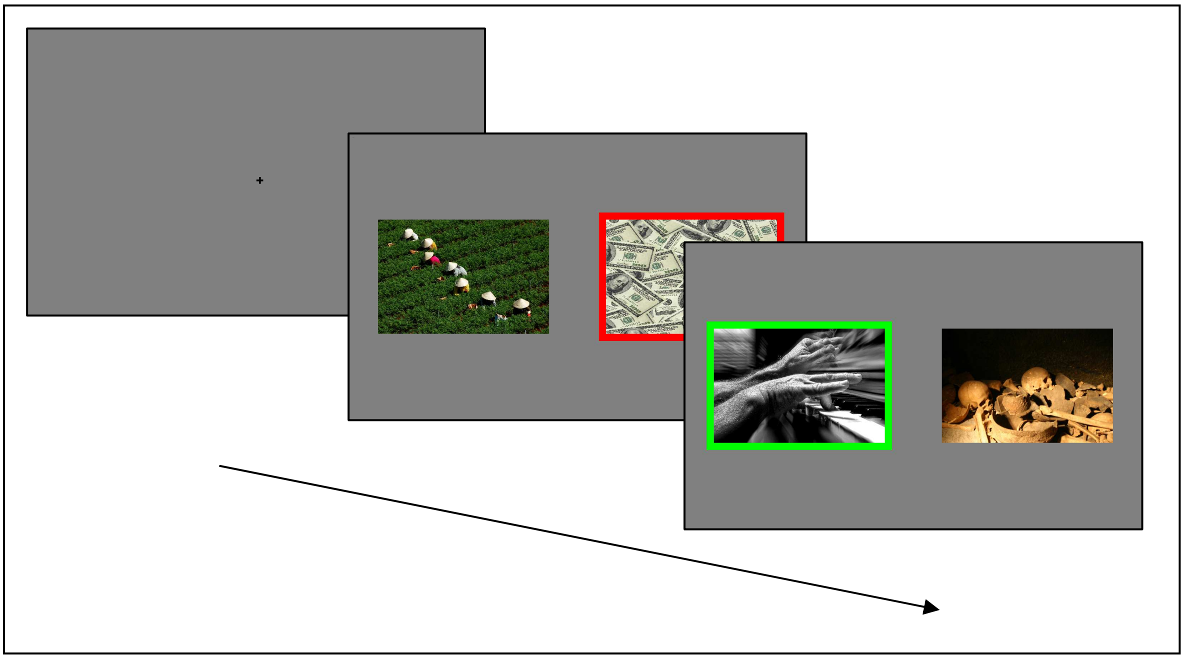
Whilst these tasks are novel and have yielded interesting findings, they do not fully address the limitation of the previous paradigms that disengagement from content is not mandatory. It is therefore conceivable that during disengage trials participants' representation of threat content remains active whilst they make their colour-naming judgement. This would potentially result in the disengagement trials in which threat information is presented generating longer response latencies than neutral trials due to pure interference (as in the conventional emotional Stroop) rather than due to delayed disengagement. Furthermore, both Hart (2005) and Sadler (2006) presented only one stimulus on screen at a time but Yiend (2004; 2010) points out that competition among multiple stimuli is necessary to evoke threat bias.

The present study introduces a new task designed to assess both vigilance for, and disengagement from, negative stimuli, and attempts to address several of the limitations of the dot-probe task and its modifications described previously as well as the issues raised with the decoupled emotional Stroop. Experiment 1 compares low and high trait-anxious individuals' performance on this task. Experiment 2 attempts to independently modify engagement and disengagement processes in mid-anxious individuals, and reports the resulting response to a trauma-analogue stressor after bias modification.

Each trial in this new task (see Figure 2.1) requires two sequential responses (like in the decoupled emotional Stroop) and the participant's first response triggers presentation of the second stimulus. This allows confidence in the location of participants' attention at the onset of the second stimulus. Like Sadler's decoupled emotional Stroop, this task includes trials which require disengagement *and* a shift in location, as well as trials which require disengagement from content but *no shift* in location. Equally, it contains trials which require engagement *and* a shift in location as well as engagement *without* a shift in location[7]. However, unlike the decoupled emotional Stroop, the new task requires two semantic judgements in quick succession and thus prevents participants from keeping the representation of the first stimulus fully active whilst making the second judgement. Also, unlike the decoupled emotional Stroop the new task discussed in this study presents two stimuli at each stage, thus providing the necessary competition between stimuli which is missing in the decoupled emotional Stroop. Finally, in addition to the benefits discussed the task lends itself to simple modifications to enable it to function as a training task. Experiment 2 is a pilot study of the training capabilities of the task.

[7] 'Engagement' and 'disengagement' obviously occur on all trials; definition of them relies upon the emotional content of stimuli presented for the first and second judgements of the trial and will be explained more clearly in the methods section of the report.

Figure 2.1: A single trial of the attention bias task



Since the main interest for experiment 1 was to investigate engagement and disengagement biases amongst high trait-anxious participants, repressors (defined as individuals reporting low trait-anxiety and high levels of social desirability) were screened out from the sample to avoid seeing an artificial vigilance-avoidance trend amongst some low trait-anxious individuals. Thus, the low-trait anxious individuals formed a more appropriate comparison group.

In both experiments 1 and 2 a variety of trait and state measures were taken (using self-report questionnaires, described in full in the next section) in order to establish in experiment 1: a) whether any group differences observed in attention biases could be attributed solely to anxiety levels, and b) whether attention biases correlated with any particular state or trait measure (including state and trait anxiety); and in experiment 2: a) whether all training groups were equivalent in these trait and states prior to training, and b) whether bias modification procedures showed any state change effect. In addition to a trait anxiety measure (STAI-T, Spielberger et al., 1983) Beck's Depression Inventory was administered (Beck et al., 1961) since co-occurrence of elevated anxiety and low mood is well documented (Gotlib, 1984). The Cognitive Avoidance Questionnaire (Gosselin et al., 2002) was also completed by participants in order to investigate whether there was any relationship between reported conscious cognitive avoidance strategies and attention biases towards (or away from) negative information. The Penn State Worry Questionnaire (Meyer et al., 1990) was the final trait measure administered and was chosen based upon Fox's (Fox et al., 2001; Fox, 2004) and Mathews' (1990) suggestions that delayed disengagement may result in increased worry, and Verkuil et al.'s (2009) observation that slowest disengagement from threat was evident in participants who were high in trait worry *as well as* anxiety.

As with the trait measures, state measures were also chosen which would shed further light upon relationships between clinically reported features of anxiety disorders and observed biases. A state anxiety measure was administered (STAI-S, Spielberger et al., 1983) as well as a more general mood visual analogue scale (Bond & Lader, 1974) which allowed for calculation of anxiety, discontentedness and sedation indices. State dissociation was also measured by self-report (adapted from Bremner et al., 1998) since elevated dissociative state has been suggested to be a common feature of elevated anxiety (Griffin et al., 1997). All these state measures were administered both before and after the attention bias assessment task (experiments 1 and 2) and before and after the stressor (experiment 2 only). This allowed calculation of change in these states and thus allowed for elimination of the possibility that any group differences in biases were due only to heightened emotional reactivity to the task. In addition to these state measures, participants were asked to report how distressing they found the attention bias assessment task (experiment 1 and 2) and the film stressor (experiment 2 only) and how much attention they had paid during the task and film.

The primary aims of experiment 1 were to investigate 1) whether patterns of engagement and disengagement which have previously been reported in high and low anxious individuals are replicable in a task which requires conscious semantic processing of stimuli, and 2) whether decoupling engagement from location maintenance and disengagement from location shifting altered the pattern of effects in high and low anxious individuals.

Experiment 2 aimed to go beyond merely measuring attention biases and look at whether modification of biases could be achieved using this same paradigm. Previous work on modification of processing biases has been based on a template of modifying biases followed by exposing participants to a stressor and measuring subsequent emotional reactivity. Stressors have varied from unsolvable anagrams (MacLeod et al., 2002), mathematical tasks (study 1, Dandeneau et al., 2007), and speech giving (Amir et al., 2008), to real-life stressors (Clarke et al., 2008; study 3a, Dandeneau et al., 2007; See et al., 2009). To date no research has looked at trauma-analogues as stressors despite the fact that Posttraumatic Stress Disorder patients have been shown to display attention bias towards threat (for a review see Buckley et al., 2000). Therefore, the primary aims of experiment 2 were to investigate 1) whether it is possible to separately train (less) engagement and (more) disengagement using the task described, and 2) whether either of these bias modifications results in an altered emotional response to a trauma-analogue stressor. Picture stimuli were utilised in order to train biases with a format which most closely matched the subsequent stressor (film) and also because altered image-based processing has been suggested to be important in PTSD (Brewin et al., 1996; Brewin et al., 2010).

In experiment 1 it was hypothesised that high anxious individuals would show speeded engagement and slowed disengagement with negative (relative to neutral) stimuli. Moreover, we expected that these effects would pervade regardless of whether individuals were required to shift location of attention or not. Low anxious individuals were hypothesised to show no differential in reaction times on negative compared to neutral trials, but were expected to show a cost (i.e. slower reaction times) on trials where they were required to shift location of attention.

In experiment 2 it was hypothesised that the interaction between time of assessment (pre, post), shift required (no shift, shift) and trial type (neutral, disengage, engage) would be different for each of the three training groups. Specific changes were hypothesised for the two training groups: engage-less training resulting in slower post-training reaction times on engage trials (but not on disengage or neutral trials), and disengage training resulting in faster post-training reaction times on disengage trials (but not neutral or engage trials). Moreover, it was anticipated that both types of training might be more effective on shift trials (compared to no shift). Finally, it was hypothesised that magnitude of participants' post-training (acquired) biases would correlate with later intrusive thoughts about the trauma film.

2.1 Method

2.1.1 Participants

Participants for the two studies were recruited in tandem. Respondents to advertisements distributed at London universities by poster and email were split into three groups (high- mid-, and low- anxious) based upon their scores on screening questionnaires (STAI-T, Spielberger et al., 1983; Marlow-Crowne Social Desirability Scale(Crowne & Marlowe, 1960) and subsequently invited to take part. Volunteers with a history of mental health problems or severe trauma (assessed by self-report) were excluded as were repressors (low anxious respondents with high social desirability scores); 21 low-anxious respondents scored >19 on the Marlow-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) and were consequently excluded. All participants had normal or corrected to normal vision and no participant was colour blind.

Experiment 1 consisted of two groups of participants: high (top 25% STAI-T scores; males scoring $\geq$ 43, females scoring $\geq$ 47; 63 of 259 respondents) and low anxious (bottom 25% of STAI-T scores; males scoring $\leq$ 33, females scoring $\leq$ 32; 64 of 259 respondents). Experiment 2 was a single-blind study in which mid-anxious participants (middle 50% of scores on the STAI-T; to males who scored >33 and <43 and females scoring >32 and <47; 132 of 259 respondents) were randomly assigned to one of three training groups; Train Engage Less (TEL, 8 participants), Train Disengage (TD, 9 participants), or No Training (NT, 11 participants).

24 males and 34 females, aged 18-36 (mean age 25.5 years) participated in experiment 1[8]. There was no significant difference between the high and low trait anxiety groups in terms of gender ratio ($\chi^2(1) = 0.05$, p=.83, high anxious, 12 males: 18 females; low anxious, 12 males: 16 females). However, as required, there was a significant difference between the groups in terms of trait anxiety scores obtained at initial screening, t(44.37)

[8] Group sizes were based upon previous work comparing attention biases in high and low trait anxious (non-clinical) individuals (e.g. Mogg & Bradley, 1999, N=40; Waters et al., 2007, N=47). Since the paradigm used in the present study is entirely new it was not possible to be confident of effect sizes and to base group sizes upon power calculations.

= -21.88, p<.001. There was also a significant difference in the age of the high and low trait anxious groups, t(37.38) = -3.01, p<.01. High trait anxious participants were older (mean = 27.2 years, standard deviation = 2.8 years) than low trait anxious participants (mean = 23.8 years, standard deviation = 4.8 years).

13 males and 15 females, aged 18 - 38 (mean age 24.3 years) participated in experiment 2. There was no significant difference between the three training groups in trait anxiety (F(2,25) = 0.59, p=.56) or gender ratio ($\chi^2(2) = 0.56$, p=.76; TEL, 3 males: 5 females; TD, 4 males: 5 females; NT, 6 males: 5 females). Nor was there any significant difference in the age of participants in the three training groups, F(2,25) = 0.86, p=.43. Participants were rewarded either with course credit or cash payment (at the standard rate of the University College London psychology department, £6 per hour). The study was approved by UCL research ethics committee (appendix A).

2.1.2 Procedure – experiment 1

All participants were tested individually. Participants began by completing trait and state characteristic questionnaires. All questionnaires used are standardised, details of each are given below. After performing the attention bias assessment (lasting approximately 15 minutes) participants completed state characteristic questionnaires (STAI-S, ADDS, MRS, and attention and distress ratings) for a second time in order to allow measurement of any change in emotional state. Finally, participants rated valence and arousal of a subset of the IAPS stimuli used in the attention bias task. The testing session lasted approximately 1 hour 15 minutes in total. All participants provided informed consent and were fully debriefed at the end of the session. No participants reported insight into hypotheses or the precise purpose of the attention bias assessment task.

2.1.3 Procedure – experiment 2

The procedure was exactly as in experiment 1 except that participants completed attention bias assessment and training task (lasting approximately 45 minutes) in place of the pure assessment task. Participants were not informed that they were being trained in any way and instructions for the task were the same as those for the pure assessment task. After completion of the second set of state characteristic questionnaires (STAI-S, ADDS, MRS, and attention and distress ratings) participants then viewed the trauma film whilst wearing apparatus to record skin conductance response and peripheral pulse (SCR and pulse data not reported here). Finally, participants in experiment 2 completed state characteristic questionnaires for a third time, and finally rated valence and arousal of a subset of the IAPS stimuli used in the attention bias task; skin conductance response and peripheral pulse were recorded whilst these ratings were made (data not reported here). The testing session lasted approximately 2 hours 30 minutes in total.

Participants returned 7 days later to complete recall and recognition memory tests for the film. For these 7 interim days they completed a daily paper diary of spontaneous intrusions. As in experiment 1, all participants provided informed consent and were fully debriefed at the end of the session. No participants reported insight into hypotheses or the precise purpose of the attention bias task.

2.1.4 Materials

Trait Measures

Spielberger State-Trait Anxiety Inventory – Form Y (STAI, Spielberger et al., 1983)

The STAI is a self-report measure of anxiety symptoms. The trait version (STAI-T) contains 20 items and requires participants to rate statements about their general anxiety on a four-point Likert scale ranging from 'almost never' to 'almost always'. Scores range from 20 to 80, with higher scores reflecting greater levels of trait anxiety. The STAI-T is one of the most commonly used measures of trait anxiety and has been shown to be a reliable and valid measure (Barnes et al., 2002).

Cognitive Avoidance Questionnaire (CAQ, Gosselin et al., 2002)

English Translation (Sexton & Dugas, 2008)

The CAQ assesses five worry-related cognitive avoidance strategies, namely Thought Suppression, Thought Substitution, Distraction, Avoidance of Threatening Stimuli, and the Transformation of Images into Thoughts. Participants rate 25 items (5 per subscale) on a five-point Likert scale ranging from 'Not at all typical of me' to 'Completely typical of me'. Scores vary from 25 to 125 with higher scores representing greater use of cognitive avoidance strategies. The CAQ has been shown to have good validity, internal consistency and test-retest reliability (Sexton & Dugas, 2008).

Penn State Worry Questionnaire (PSWQ, Meyer et al., 1990)

The PSWQ is a 16 item measure of the trait of worry. Participants rate statements related to worry on a five-point Likert scale ranging from 'Not at all typical of me' to 'Completely typical of me'. Scores vary from 16 to 80, higher scores represent higher trait worry tendencies. The PSWQ has been shown to have high internal consistency, construct validity, and test-retest reliability (Meyer et al., 1990).

State Measures

Spielberger State-Trait Anxiety Inventory – Form Y (STAI, Spielberger et al., 1983)

The STAI is a self-report measure of anxiety symptoms. The state version (STAI-S) contains 20 items where participants rate statements about their current anxiety level on a four-point Likert scale ranging from 'not at all' to 'very much so'. Scores range from 20 to 80, with higher scores reflecting greater levels of state anxiety. The STAI-S is one of the most commonly used measures of state anxiety and has been shown to be a reliable and valid measure (Barnes et al., 2002).

Beck's Depression Inventory (BDI, Beck et al., 1961)

The BDI is a reliable and well validated (Osman et al., 1997; Richter et al., 1998) 21 item self-report measure of depressive symptoms experienced during the previous week. Scores range from 0 to 63 with higher scores reflecting greater levels of depressive symptoms.

Mood Rating Scale (MRS, Bond & Lader, 1974)

The MRS consists of 16 visual analogue scales on which participants rate their current emotional state. The analogue scales are anchored at each end by opposing feelings (e.g. Alert-Drowsy, Calm-Excited, Strong-Feeble). Scores are calculated by measuring in millimetres from the end of the line to the participant's mark. Three factors can be extracted from these raw scores; anxiety, discontentedness and sedation.

Dissociative State Scale (DSS, adapted from Bremner et al., 1998)

The DSS is a 19-item self-report measure of state dissociation. Participants rate statements about their current dissociative state on a five-point Likert scale ranging from 'Not at all' to 'Extremely'. Scores vary from 0 to 76 with higher scores indicating greater dissociative state.

Attention and Distress

Participants indicated on visual analogue scales how much attention they had paid during the attention bias task (anchored by end points labeled 'None at all' and 'Total Attention') and how distressed they felt ('Not at all distressed': 'Extremely distressed'). Analogue scales were 10cm long and participants' responses were measured in millimeters.

Diary Compliance (experiment 2 only)

Participants indicated on visual analogue scales how well they had complied with the diary of intrusive memories over the preceding week (anchored by end points labelled 'not at all' and 'completely').

Attention Bias Assessment and Training Task

Experimental Hardware

A Dell Latitude e6400 laptop, with a 14.1inch, 1280x800 resolution, colour screen was used to present stimuli and record responses. Vertically neighbouring keys were remarked ‘Y’ and ‘N’ to act as response options. Stimuli presentation and response recording were managed by a program written in MATLAB 7.5.0 (Mathworks, 2007) with psychophysics toolbox (version 3.0.8).

Experimental Task

Participants were presented with 144 trials[9] where each trial consists of a fixation crosshair (200ms) followed by two “screens” being displayed consecutively (see Figure 1). In each trial participants are required to make two consecutive key-press Y/N responses. Presentation of the second “screen” is triggered by the participant’s key-press response to the first “screen”. Thus, each “screen” is displayed until the participant makes a Y/N response.

Each “screen” contains two images (selected from the IAPS; Lang et al., 2005) aligned horizontally, one of which is surrounded by a brightly coloured frame to indicate that the participant should pay attention to that image (and ignore the other). 113x75mm images were displayed 38mm apart, viewed at a distance of 500mm and subsuming visual angles 2 to15° and -2 to -15°.

As soon at the participant makes their button press response to the first “screen”, a second “screen” is displayed with the same format (two IAPS images, one highlighted by a coloured frame) and participants must shift their attention to this new stimulus and again make a Y/N decision.

Our assumption is that in order to perform the second of these button-presses accurately participants must first disengage their attention from the previous stimuli and then

[9] In experiment 2 these trials were divided into two blocks of 72 trials with one block presented before the training trials and the other afterwards. The two blocks contained different stimuli and block order was randomised.

engage with the new stimuli. By manipulating the emotional valence of the images presented we can thus assess participants' ability to disengage from, and willingness to engage with, emotional information in comparison to neutral information.

A question was selected "Does the picture in the frame contain a human being?" that required participants to engage with the content of the stimuli. A question relating to structure of the stimulus (e.g. "What colour is the frame?", "Is the picture in focus?") could also be applied and may well yield quite different results.

Attention Bias Assessment

Three types of trial were performed (see table 2.1): 1) Trials which assess participants' ability to disengage from negatively valenced images, known as *disengage* trials; 2) Trials which assess participants' tendency to engage with negatively valenced images, known as *engage* trials; and, 3) Trials which assess participants' ability to disengage from, and engage with, neutrally valenced images, known as *neutral* trials.

In the *disengage* trials one negative and one neutral image appear on screen 1 followed by the same negative and a different neutral image in screen 2. The 'frame' directs participants to attend to the negative image in screen 1 and to the neutral image in screen 2, thereby assessing participants' ability to disengage their attention from a negative image.

In the *engage* trials two neutral images appear in screen 1 followed by a different neutral and a negative image in screen 2. Participants are directed by the coloured frame to attend to a neutral image in screen 1 followed by a negative image in screen 2. Consequently, their reaction time to screen 2 represents their willingness to engage with a negative image.

In the *neutral* trials two neutral images appear in screen 1 followed by two different neutral images in screen 2. This type of trial acts as a comparison to the disengage and engage trials in terms of individual participants' ability to shift attention from one image to another (where neither image has emotional content).

On half of each trial type a shift in location of attention is required (directed by frame location in screens 1 and 2) as well as a shift in content (required in all trials). On the other half of trials only a shift in content is required and not a shift in location (frame in screen 1 and 2 are in the same location).

Participants were instructed to respond as quickly and accurately as possible. Testing began after 10 practice trials. No participants needed re-explanation after the practice or took up the offer of further practice trials. Trials were presented in a fixed, pseudorandom order. Accuracy of key-press responses was recorded along with reaction times.

Attention Bias Training

There were three training groups which differed from each other in the training phase of the task: 1) training which aimed to modify participants' ability to disengage from negatively valenced images, known as *Train Disengage* (TD); 2) training which aimed to modify participants' tendency to engage with negatively valenced images, known as *Train Engage Less* (TEL); and, 3) training which neither aimed to modify participants' ability to disengage from, or and engage with, negatively valenced images, known as *No Training* (NT).

In the trials in the *Train Disengage* condition one negative and one neutral image appear on screen 1 followed by the same negative and a different neutral image in screen 2. The 'frame' directs participants to attend to the negative image in screen 1 and to the neutral image in screen 2, thereby requiring participants' to repeatedly disengage their attention from a negative image.

In the *Train Engage Less* condition trials two neutral images appear in screen 1 followed by a different neutral and a negative image in screen 2. Participants are directed by the frame to attend to a neutral image in screen 1 followed by another neutral image in screen 2 whilst a negative image is presented alongside. As such, participants are repeatedly required to ignore (or engage less with) negative stimuli.

In the *No Training* condition four types of trials are presented with equal frequency: 1) disengage-negative trials as described above, 2) no-disengagement trials where participants are required to attend to a negative image in screen 1 and also to a negative image in screen 2, 3) engage-less trials as described above, and 4) engage trials in which participants are directed by the frame to attend to a neutral image in screen 1 followed by a negative image in screen 2. This combination of trials is designed to act as a comparison to the train disengage and train engage less conditions. In the no training condition the idea is that no contingencies are set up to encourage participants to modify their biases towards/away from negative stimuli in any way. At the same time, individual participants' ability to shift location and focus of attention is practiced (regardless of valence) with equal frequency to the other two training groups.

In all training conditions, half of the trials require a shift in location of attention (directed by frame location in screens 1 and 2) as well as a shift in content (required in all trials). On the other half of trials only a shift in content is required and not a shift in location (frame in screen 1 and 2 are in the same location). Thus, the training conditions should not differentially modify participants' ability to shift the location of their attention. Each training phase consisted of 384 trials.

Stimuli

The experimental design required image pairs to be combined in 3 ways to create the necessary assessment phase trials (see Table 2.1). There were 48 of each trial (24 involving a shift in location) resulting in a need for 96 negative images and 480 neutral images. Images were selected from the IAPS according to the valence norms for students (Lang et al., 2005)[10]. Two sets of images were selected (set A and B) which

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[10] **Neutral images**: 1313, 1333, 1390, 1419, 1450, 1510, 1540, 1560, 1601, 1602, 1603, 1604, 1616, 1640, 1650, 1675, 1720, 1722, 1740, 1810, 1812, 1900, 1910, 1931, 1935, 1942, 1945, 1947, 2000, 2005, 2010, 2020, 2025, 2030, 2037, 2038, 2092, 2102, 2104, 2152, 2153 ,2190, 2191, 2200, 2206, 2210, 2214, 2215, 2220, 2221, 2222, 2235, 2240, 2250, 2270, 2271, 2272, 2280, 2303, 2305, 2312, 2320, 2339, 2344, 2351, 2352, 2357, 2362, 2370, 2372, 2373, 2375.2, 2381, 2383, 2385, 2387, 2389, 2391, 2393, 2397, 2410, 2435, 2440, 2441, 2442, 2445, 2446, 2480, 2485, 2490, 2493, 2495, 2499, 2500, 2501, 2506, 2512, 2513, 2514, 2515, 2516, 2518, 2520, 2570, 2575, 2579, 2580, 2590, 2593, 2595, 2597, 2605, 2606, 2616, 2620, 2635, 2655, 2661, 2700, 2702, 2704, 2745.1, 2749, 2770, 2780, 2791, 2810, 2830, 2840, 2850, 2880, 2890, 2980, 3005.2, 3280, 3550.2, 4000, 4001, 4002, 4004, 4005, 4006, 4100, 4150, 4180, 4220, 4225, 4230, 4233, 4235, 4240, 4255, 4274, 4275, 4279, 4310, 4320, 4460, 4470, 4500, 4503, 4510, 4520, 4530, 4531, 4532, 4533, 4534, 4535, 4538, 4542, 4559, 4561, 4571, 4572, 4574, 4598, 4601, 4603, 4606, 4609, 4611, 4613, 4614, 4617, 4623, 4624, 4625, 4631, 4645, 4650, 4669, 4677, 4750, 4770, 5000, 5010, 5020, 5030, 5120, 5130, 5201, 5220, 5250, 5300, 5390, 5395, 5410, 5471, 5500, 5510, 5520, 5530, 5531, 5532, 5533, 5534, 5535, 5593, 5611, 5622, 5626, 5628, 5629, 5635, 5661, 5711, 5720, 5731, 5740, 5750, 5764, 5781, 5800, 5814, 5849, 5870, 5875, 5890, 5900, 5950, 5970, 5971, 5972, 5973, 5990, 5991, 5994, 6150, 6250.2, 6570.2, 6900, 6910, 6930, 7000, 7002, 7004, 7006, 7009, 7010, 7025, 7031, 7034, 7035, 7036, 7037, 7038, 7039, 7040, 7041, 7042, 7043, 7044, 7046, 7050, 7052, 7053, 7055, 7056, 7057, 7058, 7059, 7060, 7080, 7090, 7095, 7096, 7100, 7110, 7130, 7140, 7150, 7160, 7161, 7170, 7175, 7179, 7180, 7182, 7184, 7185, 7186, 7187, 7188, 7190, 7192, 7195, 7205, 7207, 7211, 7217, 7224, 7233, 7234, 7236, 7237, 7238, 7242, 7247, 7248, 7249, 7250, 7281, 7283, 7284, 7285, 7289, 7291, 7320, 7325, 7340, 7350, 7351, 7352, 7390, 7402, 7410, 7430, 7460, 7470, 7472, 7475, 7481, 7482, 7484, 7487, 7488, 7490, 7491, 7493, 7495, 7496, 7500, 7501, 7503, 7504, 7506, 7508, 7510, 7545, 7546, 7547, 7550, 7560, 7570, 7590, 7595, 7600, 7620, 7640, 7700, 7705, 7710, 7820, 7830, 7900, 7950, 8010, 8021, 8031, 8032, 8033, 8041, 8050, 8090, 8116, 8117, 8120, 8130, 8160, 8161, 8162, 8186, 8191, 8192, 8205, 8211, 8220, 8232, 8241, 8280, 8300, 8311, 8330, 8340, 8341, 8371, 8400, 8460, 8465, 8466, 8467, 8475, 8500, 8600, 8620, 9045, 9046, 9070, 9080, 9156, 9160, 9171, 9182, 9210, 9390, 9417, 9470, 9472, 9582, 9700

Negative images: 1810, 2053, 2280, 2373, 2446, 2683, 2688, 2791, 2800, 2811, 3000, 3010, 3015, 3016, 3030, 3051, 3053, 3060, 3061 3062, 3063, 3064, 3068, 3069, 3071, 3080, 3100, 3101, 3102, 3110, 3120, 3130, 3140, 3150, 3181, 3225, 3301, 3400, 3500, 3530, 3550, 4574, 6200, 6210, 6212, 6213, 6230, 6242, 6243, 6250, 6260, 6300, 6312, 6313, 6315, 6350, 6360, 6370, 6510, 6540, 6550, 6560, 6570, 6571, 6821, 6825, 6831, 6834, 6838, 7175, 7340, 7501, 8162, 8230, 8232, 8485, 9050, 9182, 9250, 9253, 9254, 9400, 9405, 9410, 9419, 9420, 9421, 9423, 9424, 9425, 9426, 9427, 9428, 9429, 9430, 9433, 9435, 9611, 9635.1, 9900, 9901, 9902, 9903, 9910, 9911, 9912, 9920, 9921 contained equivalent sets of negative (mean valence set A = 2.20, mean valence set B = 2.30, $F(1, 94) = 1.26$, $p=.27$) and neutral (mean valence set A = 5.70, mean valence set B = 5.67, $F(2,478) = 0.10$, $p=.75$) images. Stimuli pairings were drawn at random and were the same for all participants. Set A was presented first followed by set B for half of participants, set B followed by set A for the remainder.

Negative and neutral images, as required, differed significantly in their standardised ratings of valence ($t(286.57)=54.51$, $p<.001$) and arousal ($t(214.56)=-25.11$, $p<.001$).

Table 2.1: Attention Bias Assessment Task Trial Types

Trial Type	Screen 1	Screen 2	Frame 1	Frame 2
Neutral	**Neutral-Neutral**	**Neutral-Neutral**	**Neutral**	**Neutral**
Engage	**Neutral-Neutral**	**Neutral-Negative**	**Neutral**	**Negative**
Disengage	**Neutral-Negative**	**Neutral-Neutral**	**Negative**	**Neutral**

All participants in experiment one completed valence and arousal ratings for a subset of the experimental images. Twenty-five images (15 neutral and 10 negative) selected at random from the 556 experimental images were displayed individually on a 16.5 inch monitor. Standard instructions for defining these concepts were followed (Lang et al., 2005) and participants rated valence and arousal on 9 point pictorial scales.

In experiment one participants' valence and arousal ratings for negative and neutral images differed significantly as expected; valence $t(56) = 24.79$, $p<.001$, arousal $t(56) = -13.75$, $p<.001$. High and low anxious participants did not differ significantly in their valence ratings of negative ($t(55) = 0.94$, $p=.35$) or neutral ($t(55) = 0.92$, $p=.36$) images. Nor did they differ in their arousal ratings of negative images ($t(55) = -0.29$, $p=.77$). However, high anxious participants did rate neutral stimuli as significantly more arousing than did low anxious participants ($t(55) = -2.52$, $p<.05$).

Trauma film (experiment 2 only)

The trauma video comprises 12.5 minutes of real-life footage (compiled by Steil 1996) made up of five scenes of the aftermath of road traffic accidents. The footage includes injured and distressed individuals, dead bodies being moved, injured individuals screaming, body parts amongst the wreckage, and emergency service personnel attending to individuals. Each scene is introduced by a voice-over commentary outlining the background to the road traffic accident and the individuals involved.

Previous studies have used the same trauma film (e.g. Bisby, Brewin, Leitz & Curran, 2009; Brewin & Saunders, 2001; Holmes, Brewin & Hennessy, 2004) and have found no continued distress following the end of the experiment. The content of the film is similar to what one might see on the news or other factual television programmes or documentaries.

Diary of Intrusions (experiment 2 only)

Participants were instructed to complete a daily diary of any memory intrusions during the 7 days following viewing the trauma film. At the end of the first experimental session, individuals were given the prepared diary and informed that a memory intrusion was ‘spontaneously occurring’. They were instructed to take time each day to complete the diary even if zero intrusions occurred. They received alerts via text message each evening to remind them to fill in the diary.

For each intrusion participants were required to note whether the intrusion was 1) an image, thought, or combination of these, 2) the content of the intrusion, and 3) how spontaneous or automatic the intrusion was (rated 0=not at all, to 100=extremely). As spontaneous image-based intrusions are a primary symptom of PTSD, intrusions which were rated as less than 80 on the spontaneity scale were excluded from the analysis, as were any thoughts.

Follow-up assessment at one week (experiment 2 only)

Cued recall

A 20-item (four items per scene) cued recall test assessed memory for the five scenes of the trauma film. This measure is the same as used by Bisby et al. (2009).

Recognition memory

A 35-item forced choice test assessed recognition memory for the five scenes of the trauma film. Four options per question were provided; six questions per scene were presented. Each set of six questions was equally divided into three questions tapping gist memory and three tapping detail memory. This measure is the same as used by Bisby et al. (2009).

Compliance rating

Participants indicated on a visual analogue scale level of compliance with the diary completion task over the preceding 7 days (10 cm long scale anchored by end points labeled 'None at all' and 'Completely'). Participants' responses were measured in millimeters; participants rating less than 70 percent compliance were excluded from diary and memory analyses.

2.2 Results – Experiment 1

All analyses were conducted on SPSS v.14.

2.2.1 *Trait measures*

Means and standard deviations of trait measures for high and low trait anxious groups are presented in Table 2.2. Transformations[11] were conducted on non-normally distributed variables. Variables which violated parametric assumptions[12] after transformation were subjected to non-parametric analysis.

Table 2.2: Means (and standard deviations) of trait measures with associated MANOVA F scores

	High trait anxious		Low trait anxious		F Main effect of anxiety (ANOVA)
Cognitive Avoidance Questionnaire: **TOTAL**	**78.00**	**(13.81)**	**48.50**	**(14.62)**	**60.22*** **
Cognitive Avoidance Questionnaire: **Thought suppression**	**14.00**	**(3.56)**	**7.96**	**(2.57)**	~ **
Cognitive Avoidance Questionnaire: **Thought substitution**	**16.38**	**(2.81)**	**12.68**	**(3.84)**	**52.36*** **
Cognitive Avoidance Questionnaire: **Distraction**	**17.28**	**(5.06)**	**10.79**	**(4.68)**	**25.74*** **
Cognitive Avoidance Questionnaire: **Avoid threat stimuli**	**15.41**	**(4.58)**	**8.89**	**(4.61)**	**28.60*** **
Cognitive Avoidance Questionnaire: **Transform images**	**14.36**	**(4.52)**	**8.18**	**(3.02)**	**37.27*** **
Penn State Worry Questionnaire	**57.08**	**(14.33)**	**32.25**	**(8.69)**	**48.46*** **

** significant at p<.01
*** significant at p<.001
~ N/A. Non-parametric test conducted

[11] Square root transformation performed on CAQ Avoidance of Threatening Stimuli.
[12] Non parametric analysis conducted on CAQ Thought Suppression

A 2x2 MANOVA (independent variables: sex & high/low anxiety) showed a main effect of anxiety group (F(6,45) = 20.42, p<.001) but no main effect of sex (F(6,45) = 1.65, p=.16) or interaction between sex and anxiety group (F(6,45) = 1.11, p=.37). Follow-up 2x2 ANOVAs were conducted on each trait measure. ANOVAs confirmed differences between the high and low anxious groups on all trait measures (see Table 2 for test statistics and significance levels). Non-parametric analyses revealed that participants in the high trait anxiety group (Mdn = 17.0) reported significantly higher thought suppression than participants in the low trait anxiety group (Mdn = 13.5), Kolmogorov-Smirnov *Z* = 1.80, p<.01.

2.2.2 State measures at baseline

Means and standard deviations of baseline state measures (including transformed outliers[13]) for high and low trait anxious groups are presented in Table 2.3. Transformations[14] were conducted on non-normally distributed variables. Variables which violated parametric assumptions[15] after transformation were subjected to non-parametric analysis.

Table 2.3: Means (and standard deviations) of state measures pre-attention bias task.

	High trait anxious		Low trait anxious		F
BDI (depression)	**9.71**	**(5.53)**	**3.25**	**(3.00)**	**27.74*****
STAI (state anxiety)	**43.73**	**(9.87)**	**27.11**	**(5.74)**	**70.71*****
Mood Rating Scale: Anxiety	**42.54**	**(16.11)**	**28.05**	**(14.94)**	**9.54****
Mood Rating Scale: Discontentedness	**43.43**	**(17.82)**	**24.42**	**(14.36)**	**15.65*****
Mood Rating Scale: Sedation	**43.08**	**(18.48)**	**32.35**	**(13.49)**	**3.85**
DSS (state dissociation)	**9.86**	**(7.65)**	**2.93**	**(3.46)**	~ ******

** significant at p<.01
*** significant at p<.001
~ N/A. Non-parametric test conducted

[13] Outliers were transformed for the DSS (2 outliers) and for the BDI (3 outliers) by replacing with the next highest score plus one.
[14] Reciprocal transformation performed on STAI State Anxiety, square root transformation performed on MRS Sedation and BDI.
[15] Non parametric analysis conducted on DSS.

An 2x2 MANOVA (independent variables: sex & high/low anxiety) showed a main effect of anxiety group (F (5,48) = 15.14, p<.001) but no main effect of sex (F(5,48) = 0.44, p=.82) and no interaction between sex and anxiety group (F(5,48) = 0.34, p=.88). Follow-up 2x2 ANOVAs demonstrated that the main effect of anxiety group was due to the fact that the high trait anxiety group scored significantly higher on all state measures at baseline than the low trait anxious group (F statistics reported in Table 3), except for MRS sedation (F(1,52) = 3.85, p=.06). Non-parametric analyses revealed that participants in the high trait anxiety group (Mdn = 7.0) reported significantly baseline state dissociation than participants in the low trait anxiety group (Mdn = 2.0), Kolmogorov-Smirnov *Z* = 1.74, p<.01.

2.2.3 Change in state measures (pre- to post- attention task)

Changes in state anxiety and state dissociation were calculated as percentages of baseline scores. Means and standard deviations of change in state measures (including transformed outliers[16]) for high and low trait anxious groups are presented in Table 2.4. Non-parametric tests were performed on dissociation change scores.

Table 2.4: Means (and standard deviations) of change in state measures, distress and attention scores.

	High trait anxious		Low trait anxious		F
STAI state anxiety **change (%)**	**18.82**	**(22.57)**	**18.58**	**(29.93)**	**0.00**
DSS dissociation **change (%)**	**68.11**	**(126.56)**	**46.11**	**(74.70)**	**~**
MRS anxiety **change**	**15.78**	**(20.95)**	**17.06**	**(15.94)**	**0.12**
MRS discontentedness **change**	**9.67**	**(13.31)**	**13.06**	**(10.94)**	**0.72**
MRS sedation **change**	**6.11**	**(14.85)**	**4.47**	**(9.84)**	**0.45**
Attention **score**	**83.83**	**(9.24)**	**87.70**	**(10.20)**	**1.96**
Distress **score**	**55.62**	**(22.29)**	**33.30**	**(21.07)**	**16.34*** **

*** significant at p<.001
~ N/A. Non-parametric test conducted

An 2x2 MANOVA (independent variables: sex & high/low anxiety) showed a main effect of anxiety group (F (6,47) = 4.23, p<.01) but no main effect of sex (F(6,47) = 1.61, p=.16) and no interaction between sex and anxiety group (F(6,47) = 0.53, p=.79).

[16] Outliers were transformed for MRS discontentedness change (4 outliers) and attention scores (4 outliers) by replacing with the next highest score plus one.

Follow-up 2x2 ANOVAs demonstrated that the main effect of anxiety group was due to the fact that reported distress was significantly higher in the high trait anxious group than in the low trait anxious group ($F(1,52) = 16.34$, $p<.001$). Distress was also significantly higher in females than in males (Female mean = 51.38, Male mean = 34.52, $F(1,52) = 9.27$, $p<.01$). There were no significant differences between high and low anxious groups in any other emotional state change measures (F statistics reported in Table 4). Non-parametric analyses revealed that high and low anxious participants did not differ in their change in state dissociation (high anxiety Mdn = 41.88; low anxiety Mdn = 3.57).

2.2.4 Attention bias assessment task

One participant was excluded from the attention bias assessment task analyses due to a technical error recording response times. Additionally, 7 participants made errors on over 25% of trials and were consequently excluded. Therefore, N=50 for the remainder of these analyses. All reaction times analysed are response times to screen two. Median reaction times ($t(49) = -0.28$, $p=.78$) and error rates ($t(49)=1.14$, $p=.26$) did not differ for datasets A and B. Consequently, data from the two datasets are merged for the remainder of analyses.

For each participant, trials with incorrect responses were removed along with trials that contained reaction times longer than 2000ms or shorter than 200ms, and subsequently, trials more than 2 standard deviations from the participant's mean, before median reaction times were calculated for each trial type. There were no differences between high and low anxiety groups in error rates (High anxious mean = 19.87 errors, Low anxious mean = 14.22, $t(55) = -1.67$, $p=.10$) or number of trials excluded as outliers (High anxious mean = 3.27 trials, Low anxious mean = 4.56, $t(55) = 1.63$, $p=.11$).

Means and standard deviations of median reaction times for high and low anxious participants are shown in Table 2.5.

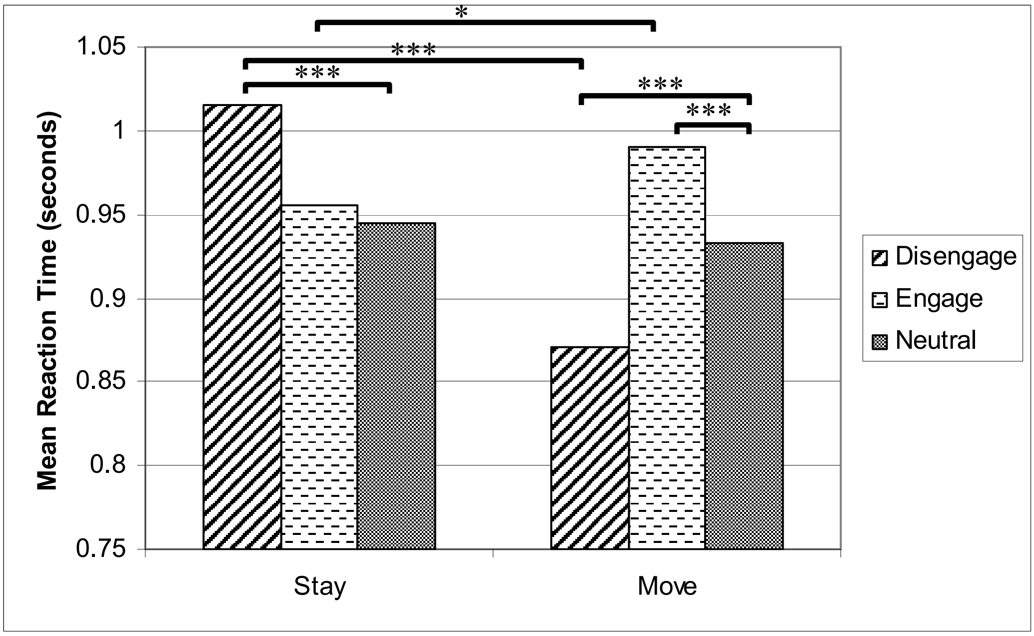
Table 2.5: Means (and standard deviations) of median reaction times (in seconds) on attention bias assessment task.

		Disengage	Engage	Neutral
High Anxious	Stay	**1.09 (0.22)**	**1.03 (0.28)**	**1.01 (0.19)**
	Move	**0.93 (0.21)**	**1.05 (0.24)**	**0.97 (0.19)**
Low Anxious	Stay	**0.94 (0.20)**	**0.88 (0.21)**	**0.88 (0.18)**
	Move	**0.81 (0.17)**	**0.93 (0.21)**	**0.90 (0.18)**

A 2 (anxiety group; low, high) x2 (shift; stay, move) x3 (trial type; disengage, engage, neutral) mixed ANOVA revealed main effects of anxiety ($F(1,48) = 5.07$, $p<.05$; high anxious participants' reaction times longer than low anxious participants'), shift ($F(1,48) = 19.78$, $p<.001$; reaction times on stay trials longer than reaction times on move trials), and trial type ($F(2,96) = 5.86$, $p<.01$; reaction times on engage trials longer than those on disengage or neutral trials). Interactions were significant between shift and trial type ($F(2,96) = 44.18$, $p<.001$; Figure 2) and shift and anxiety group ($F(1,48) = 4.53$, $p<.05$; Figure 3). Interactions between trial type and anxiety group ($F(2,96) = 1.44$, $p=.24$) and shift, trial type and anxiety group ($F(2,96) = 0.33$, $p=.72$) were non-significant.

Post-hoc analyses on the shift x trial type interaction (Figure 2.2) revealed that reaction times were significantly longer on disengage-stay than disengage-move trials ($t(49) = -9.32$, $p<.001$), and on engage-move than engage-stay trials ($t(49) = 2.11$, $p<.05$), but there was no significant difference between reaction times on move and stay neutral trials ($t(49) = -0.91$, $p=.37$). There were also significant differences between disengage and neutral stay trials ($t(49) = 4.62$, $p<.001$), disengage and neutral move trials ($t(49) = -4.90$, $p<.001$), and engage and neutral move trials ($t(49) = 4.13$, $p<.001$), but not between engage and neutral stay trials ($t(49) = 0.69$, $p=.50$).

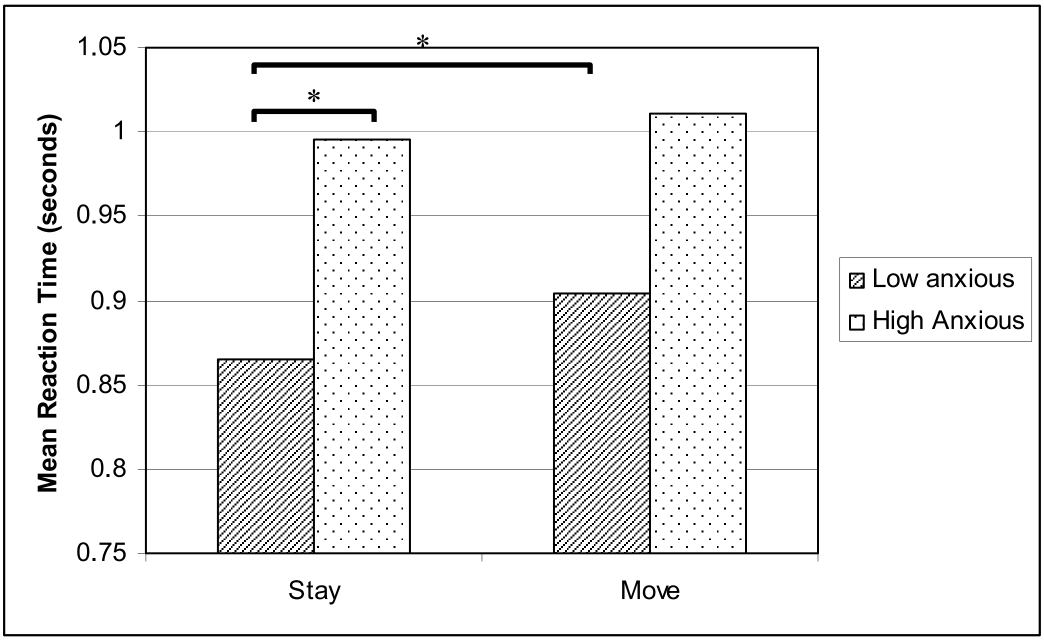
Figure 2.2: Mean median reaction times for each trial type for all participants.



*   significant at p<.05
*** significant at p<.001

Follow-up comparisons of the shift x anxiety interaction (Figure 2.3) revealed that high anxious individuals were significantly slower on stay trials than were low anxious individuals (t(48) = -2.28, p<.05) but that the two anxiety groups did not differ on move trials (t(48) = -1.87, p=.07). Additionally, high anxious individuals did not show a difference in reaction times on move and stay trials (t(23) = 1.37, p=.19) but low anxious individuals did (t(25) = 2.43, p<.05).

Figure 2.3: Mean median reaction times for move and stay trials for high and low anxious participants.



*   significant at p<.05

2.3 Results – Experiment 2

All analyses were conducted on SPSS v.14. N=28 for all state and trait measure analyses.

2.3.1 Trait measures

Means and standard deviations of trait measures (including transformed outliers[17]) for the three training groups are presented in Table 2.6. Non-parametric analyses were conducted on PSWQ worry which violated the assumption of homogeneity of variance.

Table 2.6: Means (and standard deviations) of trait measures for each training group, with associated ANOVA F scores (main effect of training group) and significance levels

	Train Disengage	Train Engage Less	No Training	F	p
STAI-T Trait anxiety	**36.33 (2.45)**	**38.13 (4.19)**	**37.18 (3.43)**	**0.71**	**.50**
Cognitive Avoidance Questionnaire: **TOTAL**	**50.67 (18.94)**	**60.13 (21.57)**	**60.63 (14.90)**	**0.97**	**.39**
Cognitive Avoidance Questionnaire: **Thought suppression**	**12.67 (3.16)**	**13.13 (2.59)**	**13.91 (1.81)**	**0.89**	**.43**
Cognitive Avoidance Questionnaire: **Thought substitution**	**8.78 (2.11)**	**10.88 (4.26)**	**10.55 (3.33)**	**0.85**	**.44**
Cognitive Avoidance Questionnaire: **Distraction**	**10.00 (4.90)**	**14.88 (5.17)**	**14.00 (4.94)**	**3.18**	**.06**
Cognitive Avoidance Questionnaire: **Avoid threat stimuli**	**9.56 (5.55)**	**11.75 (5.82)**	**12.55 (5.11)**	**0.91**	**.42**
Cognitive Avoidance Questionnaire: **Transform images**	**9.67 (4.42)**	**9.88 (4.97)**	**10.55 (4.08)**	**0.19**	**.83**
Penn State Worry Questionnaire	**38.22 (13.08)**	**44.25 (13.79)**	**46.20 (15.65)**	**~**	**.46**

~ N/A. Non-parametric test conducted

[17] Outliers were transformed for CAQ thought suppression (1 outlier) by replacing with the next highest score plus one.

An 2x3 MANOVA (independent variables: sex & training group) showed no main effect of training group (F(14,34) = 1.42, p=.20) or sex (F(7,16) = 0.59, p=.76) or interaction between sex and training group (F(14,34) = 1.86, p=.07). Follow-up 2x3 ANOVAs were conducted on each trait measure. As noted previously, and required by the experiment, participants in the three groups did not differ significantly in STAI-T scores (F(2,22) = 0.71, p=.50). ANOVAs also confirmed that there were no significant differences between training groups on any other trait measures (see Table 2 for test statistics) although there was a trend towards a difference between the three groups in their reported tendency to distract themselves from unpleasant thoughts (CAQ distraction), F(2,25) = 3.18, p=.06. Non-parametric analyses revealed that participants in the three training groups did not report significantly different PSWQ worry scores, $\chi^2(2) = 1.57$, p=.46.

2.3.2 State measures at baseline

Means and standard deviations of baseline (prior to attention training and viewing of trauma film) state measures (including transformed outliers[18]) for all three training groups are presented in Table 2.7. Logarithmic transformations[19] were conducted on skewed variables.

Table 2.7: Means (and standard deviations) of STAI-S, DSS, and MRS subscale scores for each training group at baseline (start of experimental procedure) and associated MANOVA F-scores (for main effect of training group).

	Train Disengage	Train Engage Less	No Training	F	p
BDI depression	**5.22 (5.19)**	**4.62 (4.60)**	**5.27 (3.72)**	**0.02**	**.98**
STAI state anxiety	**28.89 (4.28)**	**25.88 (5.36)**	**30.36 (5.30)**	**1.30**	**.29**
MRS anxiety	**30.50 (9.99)**	**21.13 (11.86)**	**25.59 (13.36)**	**0.98**	**.39**
MRS discontent	**29.71 (9.29)**	**27.10 (15.88)**	**30.49 (11.11)**	**0.02**	**.99**
MRS sedation	**29.36 (7.93)**	**34.90 (19.27)**	**32.56 (14.08)**	**0.66**	**.53**
DSS dissociation	**2.22 (4.52)**	**5.25 (4.46)**	**8.00 (5.37)**	**3.22**	**.06**

[18] Outliers were transformed for the BDI (1 outlier), State anxiety (2 outliers), MRS anxiety (1 outlier), MRS discontentedness (2 outliers), and MRS sedation (1 outlier) by replacing with the next highest score plus one.

[19] Log(x+1) for BDI.

An 2x3 MANOVA (independent variables: sex & training group) showed no main effect of training group (F (12,36) = 1.48, p=.18) or of sex (F(6,17) = 0.92, p=.51) and no interaction between sex and anxiety group (F(12,36) = 0.72, p=.73). Follow-up 2x3 ANOVAs demonstrated that the training groups did not differ significantly from each other on any of the state measures at baseline (F statistics reported in Table 2.7) although there was a trend towards a difference in baseline dissociation across the three groups, F(2,25) = 3.22, p=.06.

2.3.3 Change in state measures

Changes in state anxiety were calculated as a percentage of baseline scores, all other changes in state measures were analysed as point changes.

Change in state measures from pre- to post- attention bias task

Means and standard deviations of change in state measures (including transformed outliers[20]) from before to after the attention bias task, for each training group, are presented in Table 2.8. DSS dissociation change had two missing data points (N=26).

Table 2.8: Means (and standard deviations) of change in STAI-S, change in DSS, change in MRS subscales, and distress and attention scores for each training group, pre- to post- attention bias task.

	Train Disengage	Train Engage Less	No Training	F	p
STAI state anxiety **change (%)**	**24.71 (21.82)**	**30.21 (17.77)**	**25.47 (26.69)**	**0.02**	**.99**
DSS dissociation **change**	**1.63 (4.47)**	**1.25 (1.28)**	**4.00 (4.69)**	**1.31**	**.29**
MRS anxiety **change**	**11.72 (20.84)**	**18.44 (16.71)**	**9.64 (20.08)**	**0.51**	**.61**
MRS discontentedness **change**	**7.78 (13.52)**	**12.00 (12.58)**	**15.51 (14.47)**	**0.66**	**.53**
MRS sedation **change**	**7.35 (11.13)**	**4.46 (17.05)**	**13.48 (22.12)**	**0.45**	**.65**
Attention **score**	**77.89 (15.20)**	**82.88 (11.42)**	**74.18 (14.13)**	**0.64**	**.54**
Distress **score**	**35.56 (25.66)**	**44.38 (26.65)**	**45.45 (19.02)**	**0.33**	**.72**

[20] Outliers were transformed for STAI-S change (1 outliers) and DSS change (3 outliers) and attention score (2 outliers) by replacing with the next highest score plus one.

Three-way ANOVAs showed that state changes from before the attention bias task to after were not significantly different in the 3 training groups (F statistics and significance levels are presented in table 2.8) on any of the state measures. Consequently, we can surmise that the three groups did not differ in emotional state at the start of the trauma film.

Change in state measures from pre- to post- trauma film

Means and standard deviations of change in state measures (including transformed outliers[21]) from before to after the film, for each training group, are presented in Table 2.9. Non-parametric analyses were conducted on attention scores which were skewed and on dissociation change and MRS sedation change which both violated the assumption of homogeneity of variance. Dissociation change had two missing data points (N=26) and state anxiety change one missing data point (N=27).

Table 2.9: Means (and standard deviations) of change in STAI-S, change in DSS, change in MRS subscales, and distress and attention scores for each training group, pre- to post- trauma film.

	Train Disengage	Train Engage Less	No Training	F	p
STAI state anxiety	**2.43 (16.56)**	**10.49 (22.51)**	**14.24 (22.59)**	**1.24**	**0.31**
DSS dissociation	**-0.50 (0.93)**	**-2.75 (3.11)**	**-1.00 (4.29)**	~	**0.46**
MRS anxiety	**-0.17 (14.80)**	**-2.06 (9.51)**	**15.23 (9.44)**	**9.07**	**0.001*****
MRS discontent	**-0.40 (7.05)**	**1.83 (9.40)**	**6.18 (10.09)**	**1.26**	**0.30**
MRS sedation	**-5.22 (6.04)**	**1.78 (5.60)**	**-10.48 (13.91)**	~	**0.05**
Attention **score**	**84.44 (10.44)**	**75.38 (23.74)**	**82.27 (14.62)**	~	**0.94**
Distress **score**	**40.56 (22.42)**	**41.38 (28.74)**	**47.45 (22.69)**	**0.27**	**0.76**

*** significant at p<.001
~ N/A. Non-parametric test conducted

Three-way ANOVAs showed that anxiety changes from before to after the trauma film were significantly different in the 3 training groups (F statistics and significance levels are presented in table 2.9) but not on any of the other state measures. Both the Train Disengage (t(18) = 2.83, p<.05) and the Train Engage Less (t(17) = -3.93, p<.01) groups

[21] Outliers were transformed for DSS change (2 outliers), MRS anxiety change (2 outliers), MRS discontentedness change (1 outlier), and MRS sedation change (2 outliers) by replacing with the next highest score plus one. Importantly, all these outliers were amongst participants in the No Training group.

reported a lower anxiety change than the No Training group[22]. However, the two training groups did not differ from each other (t(15) = -0.31, p=.76). Non-parametric analyses revealed that participants in the three training groups did not report significantly different change in dissociation ($\chi^2(2) = 1.54$, p=.46) or post-film attention levels ($\chi^2(2) = 0.13$, p=.94) but did report borderline significantly different changes in MRS sedation ($\chi^2(2) = 6.07$, p=.05)[23].

2.3.4 Attention bias training task

Only trials during the two assessment phases (before and after training) were analysed. For each participant, trials were removed that contained reaction times longer than 2000ms, shorter than 200ms, were incorrect, or were more than 2 standard deviations from the mean. Median reaction times for each trial type prior to, and after, training were then calculated for each participant. Participants who made errors on more than 25% of trials either pre- or post- training were excluded. Consequently, N=25 for all analyses in this section.

The remaining participants in the three training groups (Train Disengage, N=9; Train Engage Less, N=7; No Training, N=9) did not differ in the number of trials excluded as outliers prior to (F(2,22) = 1.97, p=.16) or after (F(2,22) = 1.29, p=.30) training. Nor did the three groups differ in the number of trials excluded due to errors in the assessment phase after training (F(2,22) = 2.19, p=.13). However, the three groups did differ in the number of trials excluded due to errors in the assessment phase prior to training (F(2,22) = 3.35, p=.05). Pairwise comparisons showed that the No Training group did not differ significantly from either of the two training groups in pre-training error rate (Train Disengage, t(16) = -1.37, p=.19; Train Engage Less, t(14) = 1.33, p=.21) but that participants in the Train Disengage group had significantly more errors in the pre-training phase than participants in the Train Engage Less group (t(14) = 2.54, p<.05).

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[22] The Train Disengage (t(9) = -0.03, p=.97) and Train Engage Less (t(7) = -0.61, p=.56) anxiety change did not differ significantly from zero unlike the No Training group (t(10) = 5.35, p<.001).

[23] A significant difference in MRS sedation change was found between Train Disengage and Train Engage Less groups (Train Disengage Mdn = -6.44, Train Engage Less Mdn = -0.22; Kolmogorov-Smirnov *Z* = 1.34, p=.05) but not between the No Training group (Mdn = -10.00) and Train Disengage participants (Kolmogorov-Smirnov *Z* = 1.01, p=.26) or between the No Training and Train Engage Less groups (Kolmogorov-Smirnov *Z* = 1.17, p=.13).

There was no main effect of stimuli set (A and B) on reaction times (F(1,23) = 0.44, p=.51) in a 2 (assessment phase; pre, post) x 2 (shift; stay, move) x 3 (trial type; disengage, engage, neutral) x 2 (stimuli set; A, B) ANOVA. Consequently, data from the two stimuli sets were merged for all analyses. Means and standard deviations of median reaction times pre-training are displayed in Table 2.10, and after-training means and standard deviations are displayed in Table 2.11.

Table 2.10: Means (and standard deviations) of median reaction times on each trial type for participants in the three training groups prior to training

		Disengage	Engage	Neutral
Train Disengage	Stay	**0.97 (0.26)**	**0.86 (0.21)**	**0.89 (0.21)**
	Move	**0.85 (0.19)**	**0.91 (0.17)**	**0.86 (0.20)**
Train Engage Less	Stay	**1.11 (0.31)**	**1.03 (0.25)**	**1.02 (0.28)**
	Move	**0.87 (0.21)**	**0.96 (0.18)**	**0.97 (0.23)**
No Training	Stay	**1.12 (0.19)**	**1.09 (0.31)**	**1.01 (0.27)**
	Move	**0.96 (0.22)**	**1.06 (0.28)**	**0.97 (0.25)**

Table 2.11: Means (and standard deviations) of median reaction times on each trial type for participants in the three training groups after training

		Disengage	Engage	Neutral
Train Disengage	Stay	**0.81 (0.18)**	**0.73 (0.17)**	**0.78 (0.24)**
	Move	**0.67 (0.14)**	**0.80 (0.16)**	**0.77 (0.13)**
Train Engage Less	Stay	**0.97 (0.23)**	**0.88 (0.22)**	**0.85 (0.18)**
	Move	**0.89 (0.20)**	**0.96 (0.25)**	**0.87 (0.15)**
No Training	Stay	**0.90 (0.25)**	**0.86 (0.24)**	**0.87 (0.28)**
	Move	**0.84 (0.21)**	**0.96 (0.28)**	**0.91 (0.29)**

Pre-training biases

A 2 (shift; stay, move) x 3 (trial type; disengage, engage, neutral) x 3 (training group; train disengage, train engage less, no training) ANOVA on pre-training-task reaction times revealed a main effect of shift ($F(1,22) = 11.18$, $p<.01$; move trials showing faster reaction times than stay trials) and a significant interaction between shift and trial-type ($F(2,44) = 10.77$, $p<.001$). There were no significant main effects of trial-type ($F(2,44) = 1.10$, $p=.34$) or group ($F(2,22) = 1.07$, $p=.36$). Nor were significant interactions seen between shift and group ($F(2,22) = 1.05$, $p=.37$), trial-type and group ($F(4,44) = 1.02$, $p=.41$) or shift, trial-type and group ($F(4,44) = 0.35$, $p=.85$).

This pattern of results is close to those seen in experiment 1, showing that mid-anxious participants have potentially similar patterns of responding on this task to high and low anxious participants. Importantly, the three randomly-assigned groups did not differ in their pre-training patterns of response.

Follow-up analyses were conducted on the shift*trial-type interaction. Pairwise comparisons showed significant differences between disengage and neutral stay trials ($t(24) = 3.44$, $p<.01$) and between disengage stay and disengage move trials ($t(24) = -5.71$, $p<.001$). Additionally, significant differences were seen between disengage and neutral move trials ($t(24) = -2.18$, $p<.05$) and between engage and neutral move trials ($t(24) = 2.20$, $p<.05$). These findings replicate those seen in experiment 1. In contrast to experiment 1, no significant difference was shown between engage stay and engage move trials ($t(24) = -0.36$, $p=.72$).

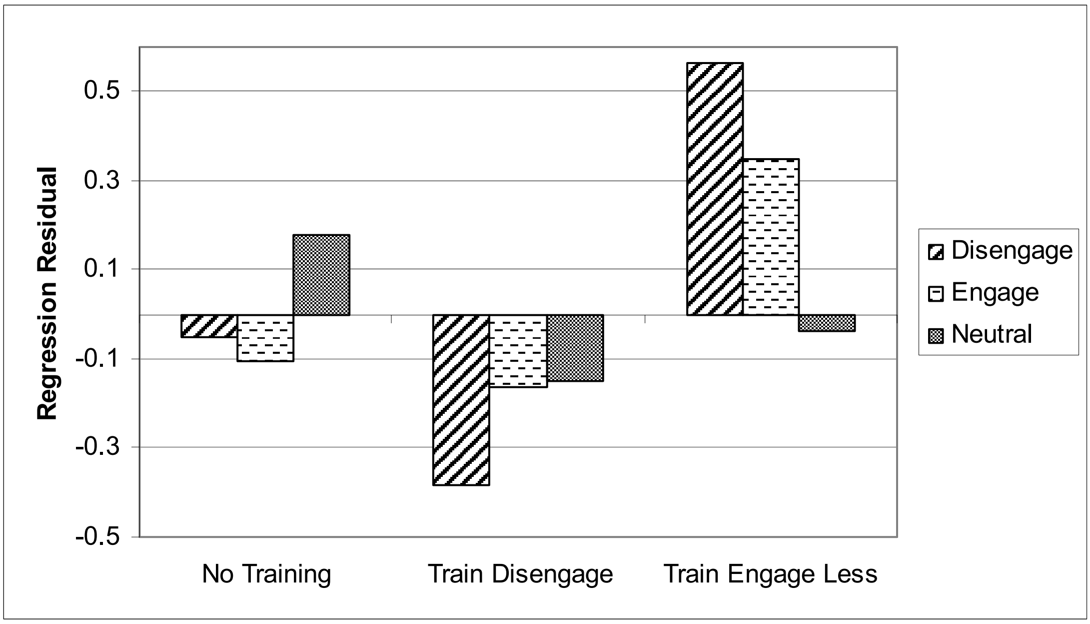
Post-training biases

Residual post-training reaction times[24] were calculated for each trial type controlling for pre-training reaction times. A 2 (shift; stay, move) x 3 (trial type; disengage, engage, neutral) x 3 (training group; Train Disengage, Train Engage Less, No Training) ANOVA on these residuals revealed no significant main effects or interactions.

[24] Residuals shown in figure 2.4 can be considered as representations of the mean amount which post-training biases differed from what might be expected based on pre-training biases.

However, there was a trend towards a significant interaction between trial type and group (F(4,44) = 2.09, p=.10; Figure 2.4).

Figure 2.4: Mean residuals for each trial type and training group, collapsing across shift/no-shift trials.



2.3.5 *Diary of intrusive memories*

Four participants who rated less than 70 percent diary compliance were excluded from diary and memory analyses as was one participant who did not return for the 7 day follow-up, leaving N=20 for analyses[25]. Means and standard deviations of number of intrusive images (including transformed outliers[26]) for all three training groups are presented in Table 2.12. All dependent variables were skewed and required transformation (Log(x+1)) before parametric analysis.

Table 2.12: Means (and standard deviations) of number of intrusive images for each training group.

	Train Disengage	Train Engage Less	No Training
Film	**3.75 (5.39)**	**2.00 (1.41)**	**6.33 (5.39)**
Pictures	**9.00 (8.38)**	**2.00 (1.90)**	**14.17 (7.76)**

Number of intrusions of the film did not differ between the three training groups (F(2,17) = 1.08, p=.36). However, there was significant difference between training groups in the number of intrusions of the IAPS pictures (F(2,17) = 8.30, p<.01). The Train Engage Less group had significantly fewer intrusions of the pictures than participants in the No Training group (t(10) = -4.60, p<.01) and participants in the Train Disengage group (t(12) = -2.63, p<.05). Participants in the Train Disengage group did not show less intrusions of the IAPS pictures than participants in the No Training group (t(12) = 1.46, p=.17)[27].

[25] Three of these participants were in the no training group and the one each in the train engage less and train disengage groups. These participants did not differ significantly from the main sample in terms of reported distress after the trauma film (t(23)=-1.06, p=.30) or trait anxiety (t(23) = 1.18, p=.25).

[26] One outlier was transformed for IAPS pictures by replacing with the next highest value plus one.

[27] It is worth noting that during the training phase all participants were presented with an equal number of negative and neutral pictures. All screens in all trials for all training groups during the training phase contained both a negative and a neutral image. However, the disengage group were directed (by the location of the frame) to attend to half the negative images (all those in screen 1) as were the no training group. The engage less group were directed to attend to *none* of the negative images. Consequently, if the number of intrusions of the images were related to the number of images attention was directed towards then we would expect to see that the participants in the train engage less group had significantly fewer intrusions than both the train disengage group (true) and the no training group (true). We would also expect that the train disengage and no training groups would have equivalent numbers of intrusions of the images (true). This likely provides a good explanation for the group differences in intrusions of the task stimuli.

2.3.6 Memory at 1-week follow-up

Means and standard deviations of number of recall and recognition scores for all three training groups are presented in Table 2.13. Neither recall ($F(2,17) = 0.25$, $p=.79$) or recognition scores ($F(2,17) = 1.86$, $p=.19$) differed significantly between training groups.

Table 2.13: Means (and standard deviations) of recall and recognition scores for each training group.

	Train Disengage	Train Engage Less	No Training
Recall	**7.88 (2.17)**	**6.83 (3.97)**	**7.00 (2.97)**
Recognition TOTAL	**16.63 (1.60)**	**15.50 (2.59)**	**13.83 (3.76)**

2.4 Discussion

The present study reports a novel attention task designed to independently assess and modify both engagement and disengagement components of attention biases. Two experiments investigated differences in engagement and disengagement biases between high and low trait-anxious individuals (experiment 1) and how modification of these biases in mid trait-anxious individuals could alter subsequent emotional reactivity to a trauma-analogue stressor (experiment 2).

2.4.1 Disengagement

The findings from experiment 1 show that both high and low trait-anxious participants were *faster* to disengage from negative stimuli than neutral stimuli when they had to move the location of their attention. Conversely, both high and low trait-anxious participants were *slower* to disengage from negative stimuli than neutral stimuli when they had to maintain the location of their attention. Moreover, mid-anxious participants in experiment 2 showed the same pattern prior to bias modification. Importantly, the difference is not due to a difference in reaction times related solely to shifting location of attention; reaction times on trials containing only neutral information did not differ when a shift in location was required compared to when maintenance of location was required. Since this pattern is shown in all participants it appears to be a general mechanism which is not related to an individual's trait or state anxiety.

Previous studies have found that anxious individuals make slower responses on invalid (probe presented in different location to stimuli) threat-cued trials than on invalid neutral-cued trials (Fox et al., 2002). These invalid trials can be considered akin to the move trials reported in the present study and, therefore, the novel paradigm used in the current study does not replicate findings from existing literature and, moreover, has demonstrated the opposite pattern of results.

The existing literature regarding disengagement patterns amongst low trait-anxious individuals has been somewhat inconsistent. Low trait-anxious participants have sometimes shown no difference in reaction time to invalid emotional and invalid neutral trials (Fox et al., 2001; Fox et al., 2002) suggesting no speeding or slowing of disengagement in the presence of valenced stimuli. However, other work has shown speeded disengagement from negatively-valenced items in low anxious individuals (Egloff & Hock, 2003). The present study provides support for the second of these two alternatives; low trait-anxious individuals showed speeded reaction times on invalid negative disengagement trials relative to invalid neutral trials (i.e. speeded disengagement from negative items).

Previously, such speeded disengagement has been suggested to perform a protective function for low-anxious individuals (MacLeod et al., 1986; Williams et al., 1988) whereby moving on quickly from negative information helps to regulate emotional response. The present study demonstrates that this tendency is present in mid- and high-anxious individuals as well as in low anxious individuals and, consequently, it seems unlikely that this mechanism forms a protective function. However, it is of note that high anxious individuals were significantly slower overall than were low anxious individuals. It is therefore possible that high anxious individuals are employing the same strategies as low anxious but over a significantly longer timescale which may reflect a lack of automaticity.

One explanation for the disengagement results of the present study is that negative stimuli *speed locational disengagement* in comparison to neutral stimuli *for all individuals*. This pattern of behaviour might plausibly result from a spatial-avoidance mechanism whereby locations which have previous held negative information are subsequently avoided. If this is the case and participants are fast to disengage spatially from negative stimuli in general (i.e. avoidant of negative stimuli after engaging) then we would expect to see, as was found in the present study, slowing on trials which require maintenance of the same spatial location and speeding on trials which require shifting of spatial location (since theoretically participants have already initiated avoidance as, or before, the new stimuli is presented).

Alternatively, and in accordance with explanations offered for performance on task such as the emotional Stroop task, the pattern of results on disengagement trials might be accounted for by ongoing interference from negative content. By this account, the findings of the present study could be explained by participants having found that interference from negative items presented in screen one was greater when they maintained the location of their attention (and thus slowed reaction times) than when they were required to shift the location of their attention. This means that content disengagement is in some way *facilitated by* locational disengagement.

2.4.2 Engagement

Engagement trials showed a different pattern, although again one that was the same for both low and high trait-anxious participants in experiment 1 and for mid-anxious participants in experiment 2 (prior to bias modification). When participants were required to *maintain* the location of their attention they did not show faster or slower response times to negative than to neutral stimuli. However, when they were required to *move* the location of their attention, participants were slower to engage with negative stimuli than they were to engage with neutral stimuli. This seems to contradict suggestions from previous research that negative stimuli *draw* attention. The findings of the present study suggest that negative stimuli presented in a different spatial location to current attentional fixation actually *repel* attention when compared to neutral stimuli. In contrast, presenting negative stimuli in the vicinity of current attentional fixation does not result in slowed reaction times when compared to neutral stimuli.

Some previous studies (e.g. Carlson & Reinke, 2008; Koster et al., 2006) using modified dot-probe tasks have demonstrated *speeded* engagement with negative stimuli amongst anxious individuals (revealed when reaction times on valid threat trials are shorter than reaction times on valid neutral trials). The present study does not show such speeded engagement with negative images. Instead all individuals, irrespective of trait anxiety level, exhibited equivalent reaction times on valid negative and valid neutral trials. This is in line with the bulk of previous work on supraliminally presented stimuli (e.g. Fox et al., 2001; Koster et al., 2004; Salemink et al., 2007). Previous literature does not exist on engagement after invalid cues; previous tasks have always used invalidly cued trials as measures of disengagement, the present study is the first to report that participants are slower to engage with negative stimuli, in comparison to neutral, if they are required to shift location of attention in order to do so.

Once again, we can consider these findings in light of the spatial-avoidance account posited in the previous section. By this account, in the present study participants appear to have avoided negative stimuli which were presented away from fixation (relative to neutral) but did not avoid negative stimuli presented at fixation. If this is the case it is unlikely to reflect the same mechanism that is at work in the disengagement trials when participants have already engaged with negative stimuli and are subsequently avoidant. Avoidance on engagement trials suggests that some interpretation of the stimuli has taken place prior to allocation of attention; this is a different stage of processing to avoidance following disengagement and use of the word "avoidance" is not meant to imply that the two are related to each other or explained by the same mechanism.

Alternatively, considering the engagement trial results in light of an interference account, participants in the present study showed increased interference of negative stimuli (relative to neutral) when required to shift location of attention to the target. Conversely, they did not show increased interference of negative stimuli when required to maintain location. If we view this increased interference as a failure in inhibition of negative content then participants show a reduced capacity to inhibit negative content when it is presented away from fixation, but a maintained capacity to inhibit negative content when it is presented at fixation. This explanation fits with some previous findings; for example, threat information presented parafoveally has been found to be more useful as a prime than when presented foveally (Calvo & Castillo, 2005).

2.4.3 Shifting versus maintaining location of attention

Experiment 1 showed that high anxious individuals did not differ in their reaction times on trials in which they were required to shift compared with trials in which they maintained location of attention. By contrast, low anxious individuals showed faster reaction times on trials in which they had to maintain location of attention than in trials in which they were required to shift location. Since direct comparison with a mid anxious group is not possible this could be due to either slowing amongst high anxious individuals or speeding in low anxious participants. The mid-anxious participants in experiment two showed faster reaction times on move trials than stay trials (the reverse of what was seen in low anxious individuals in experiment one).

The interaction between anxiety group and location of attention seen in experiment 1 could reflect avoidance of previously attended locations in high anxious individuals that is not only seen on threat trials but also on trials with only neutral content. Alternatively, it could reflect slowed disengagement amongst low-anxious individuals (again, not threat-specific) or a lack of avoidance. Further work would be needed to unravel these possible explanations.

2.4.4 Self-reported emotional traits and states

In experiment 1, the high anxious group reported higher levels than the low anxious group not only of trait anxiety but also higher levels of trait worry, trait cognitive avoidance, state dissociation, state anxiety (on both scales used), state discontentedness, and state sedation and in emotional response to the task in terms of level of distress reported after the attention-bias task[28]. Interestingly high and low trait anxiety groups did not differ in terms of change in state anxiety, mood, or dissociation in response to the task or in terms of reported attention paid to the task.

The difference in reported distress between the anxiety groups is perhaps the most noteworthy of these. Several interpretations of this finding are possible. High and low anxious individuals did not differ in their valence ratings of the images but high anxious individuals did rate the neutral images as more arousing than the low anxious group did. Consequently, high anxious participants viewed more images which they considered arousing than did low anxious participants. This heightened arousal could be linked to the elevated distress reported. Alternatively, it is possible that the task itself evoked negative emotions that are linked to distress in the high anxious group. Finally, high anxious participants may have a greater tendency to experience, or to report, high levels of distress.

[28] Although the groups will be referred to as high- and low-trait anxious throughout the discussion, it is acknowledged that any differences observed between these groups are just as likely to be due to any of these other reported emotional differences or a combination of these states and traits.

2.4.5 Attention Bias Training

The training task was not effective in altering measurable biases. The three training groups did not differ in their attention biases before training and did not show differences in post-training biases after accounting for pre-training biases. However, there are some indications that the three training groups differed in their emotional response to the trauma video. The three groups did not differ in traits or baseline states. As expected from previous bias modification literature, the groups also did not differ in change in state anxiety scores or other self-reported states after bias training. However, the three groups *did* differ in anxiety change in response to the stressor (trauma video) with both the training groups showed a smaller anxiety response to the video than the no-training control group did. This result suggests that both engagement and disengagement stages in attentional bias have an effect on emotional reactivity.

With regards to longer-term processing of the trauma video, participants in the train engage-less group reported fewer intrusions (of the bias task stimuli, not of the film content) over the week following the training. It is possible that this is a feature purely of the number of negative images which participants in different training groups were required to fixate upon during the attention training task. Moreover, since the bias-modification task was not successful it is impossible to conclude that such a difference is linked to training effects. However, since the groups did not differ in trait or state measures prior to training, differences in emotional reactivity to the stressor cannot be attributed to these factors either.

Previous studies have not attempted to modify engagement and disengagement in isolation and so it is difficult to compare the present study to findings in the literature. It is possible that modification of these biases in isolation is not practically achievable or that modification of either bias in isolation would not be sufficient to yield an alteration in emotional reactivity. However, laying these issues aside, there remain several possible targets for future improvements in this paradigm which may yield more conclusive findings. First, as alluded to above, it is possible that biases were modified in some way but that the assessment phases of the task did not capture this, or that the small sample size in this study prohibited detection of group differences.

Second, it is possible that the training phase was not long enough or needed repetition in order to have a sustained effect on emotional reactivity. Follow-up work could investigate the effect of longer or multiple training periods. Third, in the present study 100 percent of trials in the training phase included the appropriate contingency (do not engage with, or disengage from, negative stimuli). This replicates MacLeod et al.'s (2002) original procedure as well as the majority of subsequent studies which have replicated this method but other work has utilised training periods where the majority rather than the totality of trials are reinforcing the appropriate associations (e.g. Amir et al., 2009a; Schmidt et al., 2009). This may be more effective given that partial reinforcement is known to lead to higher rates of responding. Finally, previous modification techniques have relied on training contingencies between valence of stimulus and location change. It may be necessary to train disengage *and* move location, for example, instead of disengage and *either* move *or* maintain location.

One final important feature of this study must be noted; the group sizes are small resulting in under-powering of the experiment. This was because the pilot study was not extended once it became apparent that the task was unable to capture bias change if it was happening and so I would be unable to draw firm conclusions about whether magnitude of changes in emotional reactivity were related to magnitude of bias changes.

2.4.6 General Discussion

Both the avoidance and interference accounts posited above seem to offer reasonable explanations for the findings. However, since the results seem to contradict much of the existing literature, close scrutiny of this new methodology is required. There are several limitations to the attention bias task employed which should be noted.

One possible criticism is that generally negative rather than threat stimuli were used. This was due to the large number of images required for non-repetition and the limited number of threat-specific items in the IAPS picture set. However, use of negative stimuli may provide one explanation for why no vigilance was detected on the engagement trials. Anxiety likely reflects the activity of the fear system and hence heightened states of anxiety could be expected to lead to increased sensitivity in the attentional system (Fox et al., 2001). It is possible that negative images do not activate the fear system in the same way that threat stimuli would. However, depressed individuals do show speeding to generally negative probes (Koster et al., 2005) and Fox et al. (2002) found evidence for delayed disengagement from negative stimuli amongst high-anxious individuals.

The task reported here differed from modified dot probe tasks in several important ways which may help to give insight into the findings reported. First, since the display time of stimuli was not restricted the processes required to perform this task were conscious and controlled and allowed for development of strategies. Indeed, some participants reported an increased desire to make responses as quickly as possible in order to 'remove' negative images from the screen. Derakshan, Eysenck & Myers (2007) propose that the vigilant stage of attending to threat information occurs rapidly and is automatic and non-conscious whilst the avoidant stage involves controlled and strategic processes and may reflect possible coping strategies. As such, this new task may be better at assessing avoidance than assessing vigilance since it allows for controlled and strategic processing. This may explain why seemingly good evidence for avoidance strategies in disengagement trials has been shown whilst no evidence for vigilance has been forthcoming from the engagement trials in this study, in contrast to what might be expected from the existing literature.

Second, the task is semantic in nature, not perceptual like many existing tasks, and as such requires that participants engage fully with, and disengage fully from, the content of each stimulus. In previous studies these processes have been assumed to be happening but the tasks employed have not ensured that it is mandatory for participants to do so. All stimuli are task-relevant in the present study therefore and full engagement with, and disengagement from, content is required on every trial. This feature may account for reaction times which are longer than those generally seen in attentional bias tasks. Semantic processing may also allow for greater interference by negative items. A comparison of the same task procedures but with directions to perform a perceptual decision may yield interesting results.

Third, this task suffers from the one of the same limitations that the modified dot probe tasks do; it does not control fully for the fact that there may be individual differences in the degree to which participants have engaged with the stimuli initially. It is possible that difficulty disengaging from a stimulus may well actually result from increased engagement and the two processes may not be entirely separable. Thus, this task may be good at capturing disengagement effect purely because these are compounded by engagement effects but they would not otherwise be discernable.

Of primary interest in this study were differences in engagement and disengagement speeds between low- and high-trait anxious participants. Whilst there was no evidence of differences in engagement or disengagement between anxiety groups, there were indications of other group differences. High anxious participants were generally slower and also showed slowing relative to low anxious individuals on trials where they were required to maintain location of attention. The high anxious group also reported greater distress after the attention bias task than did the low anxious group.

According to Processing Efficiency Theory (Eysenck & Calvo, 1992) and Attentional Control Theory (Eysenck et al., 2007) a distinction is necessary between performance effectiveness (quality of performance) and processing efficiency (related to the relationship between performance effectiveness and the effort or processing resources invested in that performance). Eysenck and colleagues propose that anxiety has a greater adverse effect on processing efficiency than on performance effectiveness. That is, anxious individuals invest increased effort or processing resources in order to attain a comparable level of performance effectiveness. Eysenck et al. (2007) suggests that a good measure of performance effectiveness is error rate whilst a good measure of performance efficiency is reaction time. As such, our high- and low-trait anxious groups fit into Eysenck & Calvo's model since they do not differ in error-rate but the high-anxious group show a greater efficiency cost (slowed reaction times) than the low anxious group. Such slowing in anxious individuals, regardless of valence has been reported previously (e.g. Bar-Haim et al., 2005). Clearly, our study cannot provide direct support for Eysenck & Calvo's theory but considering our findings in this light does suggest interesting lines for future research. Altering the level of task difficulty or providing a demanding concurrent task may probe the relationship between effectiveness and efficiency in high and low anxious individuals. Additionally, individual differences in working memory and attentional control may serve as useful predictors of behaviour.

The elevated distress reported by high anxious participants also suggests that the task may not have been performed in exactly the same way by the two anxiety groups. One obvious way to account for the emotional differences between the anxiety groups is that since high anxious participants' reaction times were generally longer than low anxious they must have looked for longer at negative pictures. This would potentially result in a greater emotional impact of the images purely due to extended exposure.

A methodological point of interest is that repressors were screened out from the volunteers when selecting the participant group. This was done to avoid 'muddying' the low anxious group with participants likely to be prone to a vigilance-avoidance pattern of responding (Derakshan et al., 2007) and is not something commonly done in other attention bias studies. Future studies could recruit a separate group of repressors and investigate whether bias differences are identifiable with this task.

With regards to experiment 2, in which I aimed to induce biases in mid-anxious participants and study the resultant reduction in emotional reactivity, it is evident even with this small scale study that the bias-modification technique was not effective. There are indications that the processing of the trauma video may have differed in the three training groups but it is not possible to link these differences to the degree of bias modification. It remains possible that the training task did modify biases but the assessment phase was not able to capture this. Possible modifications to the task were suggested above.

2.4.7 Conclusions

In summary, the results of experiment one presented suggest *speeded* content disengagement from negative stimuli relative to neutral stimuli in all participants irrespective of trait or state anxiety level when spatial location changes concurrently, but *slowed* content disengagement when spatial location of attention is maintained. These findings are different to those seen in previous work conducted on disengagement processes.

The results also show that all participants were slower to engage with negative stimuli relative to neutral stimuli when required to change spatial location, but were neither faster nor slower to engage with negative stimuli when images were presented in the vicinity of previous fixation.

There were some indications that utilising the novel attention bias task as a training task resulted in differences in processing. However, overall it was not possible to discern a measureable difference in induced biases between training groups and, consequently, not possible to link group differences in emotional processing to attention bias modification.

Two plausible explanations were offered for the findings from experiment one. First, it is possible that the results reflect a pattern of avoidance of negative stimuli during disengagement trials in support of the Vigilance-Avoidance hypothesis (Derakshan et al., 2007) as well as avoidance of negative stimuli presented away from fixation during engagement trials. However, no evidence of avoidance was seen for negative images presented at fixation during engagement trials. Possible explanations for this include freezing or heightened interference.

Alternatively, the results might be due to interference (perhaps explained by capacity to inhibit) of negative stimuli. According to this account it seems that *attentional* disengagement from content is aided by concurrent *spatial* disengagement and hindered by concurrent spatial maintenance. This would certainly fit with the widely-accepted converse, that the location of fixation of visual attention is a strong indicator of content of attention. With respect to the engagement trials, the interference-account posits that increased interference of negative content occurs when it is presented away from fixation, but not when it is presented at fixation. If such interference reflects a failure to inhibit negative content then participants are showing reduced capacity to inhibit negative content that is presented away from fixation, but maintained capacity to inhibit negative content presented at fixation. It should be noted additionally that accepting either account for the one type of trials does not necessitate accepting the same account for the other type; different mechanisms may be responsible for the patterns of behaviour seen in the engagement and the disengagement trials.

The lack of differences between anxiety groups, despite an extensive literature showing that anxious individuals show robust attention biases, may reflect increased effort from high anxious participants, which was perhaps made possible by the conscious processes that the lengthy stimuli exposures allowed. An interaction between anxiety group and move/stay trials was evident however and follow-up work could potentially cast new light on previous literature in which shifting location of attention and changing content of attention have been confounded.

Chapter 3: Replication and Extension of Attention Bias Assessment Task in High and Low Anxious Individuals

The previous chapter introduced a novel task designed to measure engagement and disengagement components of attentional bias. The results of two experiments presented there suggest that similar mechanisms are at work in all individuals irrespective of differences in trait anxiety. High, mid, and low trait-anxious participants all showed *speeded* disengagement from negative stimuli relative to neutral stimuli in trials where a move in spatial location was required, but *slowed* disengagement from negative stimuli when maintenance of location of attention was required. Additionally, all participants were slower to engage with negative stimuli relative to neutral stimuli when required to change location of attention, but were neither faster nor slower to engage with negative stimuli when they were required to maintain the spatial location of their attention. The study reported in the present chapter aims to address some of the limitations of the first of these two studies (experiment 1, chapter 2).

A number of weaknesses of the previous study were outlined in chapter 2. First, generally negative rather than threat stimuli were used. This was due to the large number of images required for non-repetition and the limited number of threat-specific items in the IAPS picture set. However, selecting pictures from the IAPS meant that, whilst all stimuli were negatively valenced, not all were threatening. It is possible that negative stimuli do not activate the fear-system in the same way as threatening stimuli would. The present study therefore aims to compare high and low trait-anxious individuals' performance on the attentional bias assessment task reported previously using threatening words as stimuli instead of negative images since it will be possible to generate a larger stimuli set this way. Bar-Haim and colleagues show in their meta-analysis (2007) that, despite theoretical criticism of reliance upon verbal stimuli in attentional bias tasks (e.g. Bradley et al., 1997b), word and picture stimuli yield similar bias sizes. Consequently we expect word stimuli to show the same pattern of results as picture stimuli did previously.

As in the experiments in chapter 2 participants will again make semantic judgements about the stimuli in order to ensure that they have engaged fully with the meaning of the first stimulus in each trial before being required to alter the content of their attention when the second stimulus appears. In addition to this replication, it is of interest to discover whether the same pattern of results will be seen if participants were not *required* to engage with the meaning of the stimuli (but are free to do so). Therefore, a block of trials in which participants are required to make judgements about only structural features of the stimuli, and not about semantic content, will be incorporated.

These two blocks require different strategies in order to achieve fast and accurate performance. In the semantic judgement block speeded reactions are achieved by speeded engagement with content, whilst in the structural block reaction times on threat trials will reflect individuals' ability to inhibit the interference of meaning of threat stimuli. This second block, therefore, may be considered as more akin to an emotional Stroop task (Stroop, 1935) where participants must ignore meaning of stimuli in order to make fast reactions.

The classic dot probe task which is heavily utilised in the attentional bias literature does not *require* any semantic processing of stimuli since responses are made only to probes. However, in studies which utilise the dot probe paradigm it is assumed that meaning of stimuli is irresistibly processed. By contrast the task reported here *necessitates conscious processing* of meaning in the semantic block and allows (but does not require, like in a dot probe task) semantic processing in the structural block. Because of the heavy reliance upon the dot probe task in the attentional bias literature studies utilising paradigms which *necessitate* semantic processing are rare.

Vythilingam and colleagues (2007) used two tasks, one which requires semantic engagement (the emotional lexical decision task; eLDT; Nakic et al., 2006) and one which does not (the affective Stroop task, aST; Blair et al., 2007). In the aST, an adaptation of the Number Stroop task (Pansky & Algom, 2002), as in an emotional Stroop task which employs verbal stimuli, valenced stimuli act as distracters and interfere with task performance. Conversely, in the eLDT emotional information improves task performance (Graves et al., 1981; Nakic et al., 2006; Lorenz & Newman, 2002; Strauss, 1983; Williamson et al., 1991). Vythilingam et al. reported that participants with posttraumatic stress disorder showed increased interference from negative items in the aST and increased facilitation for negative items on the eLDT. Consequently, it is hypothesised that high anxious individuals may show different biases to low anxious individuals on the structural block even though no anxiety group differences were shown in the previous studies using the semantic task or are expected in the semantic block in the present study.

Finally, in order to further investigate possible causes of the large discrepancy in reaction times between high and low anxious individuals, we included an assessment of working memory span. According to Processing Efficiency Theory (Eysenck & Calvo, 1992) and Attentional Control Theory (Eysenck et al., 2007) anxious individuals invest increased effort or processing resources in order to attain a comparable level of performance to low-anxious individuals. Moreover, Eysenck et al. suggest that anxiety reduces attentional control and impairs inhibition (resisting disruption or interference from task-irrelevant stimuli) and shifting functions (adaptive changes in attentional control based on task demands) of working memory. The O-Span task (Turner & Engle, 1989) included in the present study requires participants to learn word lists under cognitive load (provided by concurrent mathematical problem-solving) and measures operation span. It requires both inhibition (of mathematical tasks whilst recalling words, and words whilst performing mathematical task) and shifting functions (between mathematical task and word memorising). This task has previously been used to differentiate between participants who allocate attention as a spotlight (low working memory span on the OSPAN) and those who showed flexible allocation on a selective attention task (high working memory span on OSPAN; Bleckley et al., 2003) and generally performance on complex working memory tasks has been linked to individuals' ability to control attention (Engle, 2002; Kane et al., 2001). Furthermore, Mogg et al. (2000b) suggest that flexible allocation of attention (high working memory span) is required for effective performance on attention bias tasks. As such, it is hypothesised that high-anxious participants will show reduced working memory span in line with their altered performance on the attention bias assessment task. This hypothesis is also in line with the view that a lack of the flexible use of attention that may contribute to cognitive vulnerability towards, and maintenance of, emotional disorders (Wells, 2000).

It was hypothesised that the semantic part of the attention bias task would replicate the findings of study 1 in chapter 2. That is, 1) both high and low trait-anxious participants would be *faster* to disengage from threat stimuli than neutral stimuli when they had to move the location of their attention but *slower* when they had to maintain the location of their attention, and 2) both high and low trait-anxious participants would be as quick to engage with threat as with neutral items when they were required to *maintain* the location of their attention. However, when they were required to *move* the location of their attention, participants would be slower to engage with threat stimuli than they were to engage with neutral stimuli.

Additionally, as outlined above, it was hypothesised that the structural part of the attention bias assessment task would show a different pattern of biases. Following from patterns reported in the literature where participants have executed structural decisions during attention bias tasks, it was expected that high trait-anxious participants would display longer response latencies for threat stimuli in the structural condition compared with neutral stimuli reflecting increased interference of threat stimuli.

3.1 Method

3.1.1 Participants

19 males and 40 females, aged 18 - 25 (mean age 20.8 years) participated in the study. Participants recruited were an opportunity sample of University College London who responded to advertisements distributed at London universities by poster and email. All participants had normal or corrected to normal vision and no participant was colour blind. Participants were either recruited as part of an undergraduate research project and were either known to the experimenters or were rewarded either with course credit in return for participation.

After full data collection participants were divided in to 'low' and 'high' trait anxious groups (42.5 median division of STAI-T scores; four participants who scored either 42 or 43 were excluded)[29]. Ten respondents obtained a score greater than 19 on the Marlow-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) as well as meeting criteria for the low-anxious group, and were therefore excluded from the analyses as 'repressors'. Consequently data were analysed from 45 participants (22 participants in the high anxious group, 3 males and 19 females; 23 participants in the low anxious group, 12 males and 11 females). There was no significant difference in the ages of the high and low trait anxious groups, $t(37) = 0.24$, $p=.82$, but there was a significant difference in the gender ratio of the groups, with the high anxious group containing a significantly greater proportion of females ($\chi^2(1) = 7.52$, $p<.01$).

3.1.2 Procedure

All participants were tested individually. Participants began by completing trait and state characteristic questionnaires. All questionnaires used are standardised, details of each were given in chapter 2. After performing the attention bias assessment (lasting

[29] A median-split design was chosen in order to maximise group-size. However, using a 30th-percentile cut-off as used in some places in the literature, or a 25th-percentile cut-off as in experiment 1 in chapter 2, does not alter the main effects or interactions seen in this study.

approximately 15 minutes) participants completed the state anxiety questionnaire (STAI-S) for a second time in order to allow measurement of any change in state anxiety. Finally, participants completed a working memory span assessment (O-SPAN; Turner & Engle, 1989). The testing session lasted approximately 1 hour. All participants provided informed consent and were fully debriefed at the end of the session. No participants reported insight into hypotheses or the precise purpose of the attention bias assessment task. The study was approved by UCL research ethics committee (appendix C).

3.1.3 Materials

Trait and state measures[30] were administered as in experiment 1 in chapter 2. The hardware and computer program were identical to those reported in chapter 2.

Attention Bias Assessment

Experimental Task

Participants were presented with two blocks of 72 trials (total of 144 trials) where each trial consisted of a fixation crosshair (200ms) followed by two "screens" displayed consecutively (see Figure 3.1). The rationale and task procedure were identical to those reported in chapter 2 except that the two blocks required participants to make different types of judgement about the stimuli. In each trial participants were required to make two consecutive Y/N key-press responses. Presentation of the second "screen" was triggered by the participant's key-press response to the first "screen". Thus, each "screen" was displayed until the participant made a key-press. Each "screen" contained two words aligned horizontally in Arial, size 30 font.

Two questions were selected, one that required participants to engage with the semantic content of the stimuli ("Can you see, hear or touch this?") and one which did not

[30] Spielberger State-Trait Anxiety Inventory (Spielberger et al., 1983), Beck's Depression Inventory (Beck et al., 1961), Cognitive Avoidance Questionnaire (Gosselin et al., 2002) English Translation (Sexton & Dugas, 2008), Penn State Worry Questionnaire (Meyer et al., 1990).

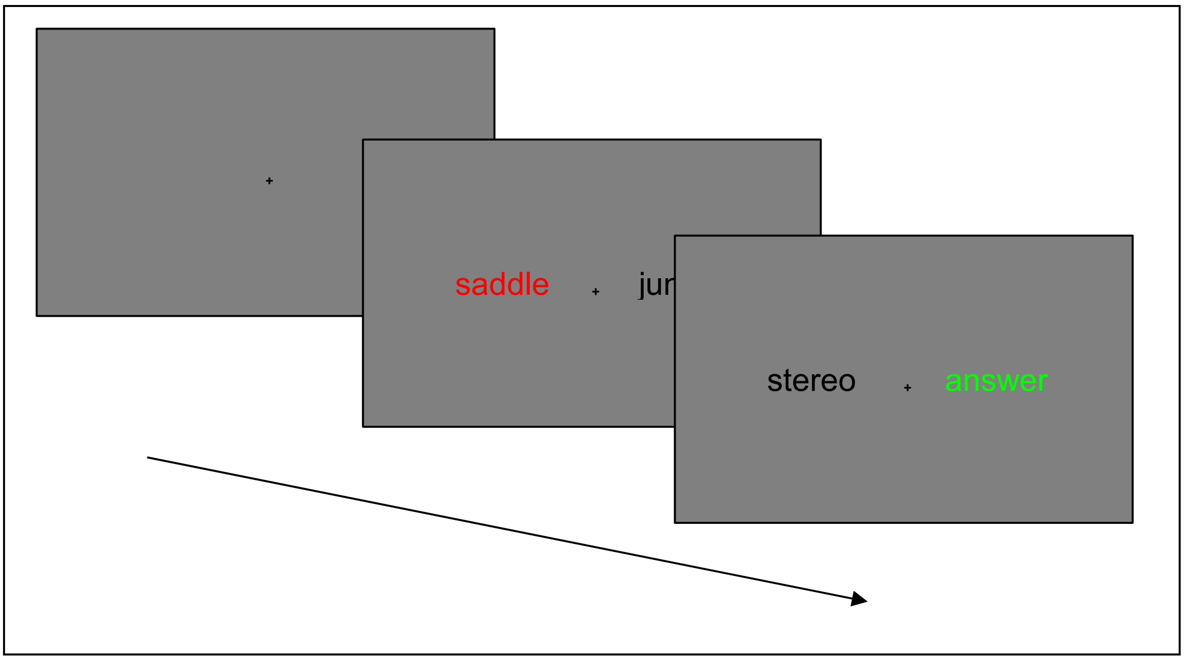
(referred to as the structural condition "Does this word start or end in a vowel?"). Participants performed one block of each of these conditions; block order was counterbalanced across participants.

As in chapter two, there were three types of trial: 1) *disengage* trials; 2) *engage* trials; and, 3) *neutral* trials. Participants were instructed to attend to words which presented in coloured font (red/green) and ignore the other word presented. Coloured font directed participants attention to threat-then-neutral (disengage trials), neutral-then-threat (engage trials), or neutral-then-neutral (neutral trials) words respectively.

On half of each trial type a shift in location of attention was required (directed by font colour in screens 1 and 2) as well as a shift in content (required in all trials). On the other half of trials only a shift in content was required and not a shift in location (highlight in screen 1 and 2 are in the same location).

Participants were instructed to respond as quickly and accurately as possible. Testing began after 10 practice trials. No participants needed re-explanation after the practice or took up the offer of further practice trials. Trials were presented in a fixed, pseudorandom order. Accuracy of key-press responses was recorded along with reaction times.

Figure 3.1: A single trial of the attention bias assessment task (with word stimuli)



Stimuli

As in experiment 1 in chapter 2, the experimental design required word pairs to be combined in 3 ways to create the necessary trials. Across the two blocks there were 48 of each trial (24 involving a shift in location) resulting in a need for 96 threat-neutral word pairs and 192 neutral-neutral word pairs. Word pairs (appendix B) were selected from a list of 890 words (190 'threat' words, 700 'neutral' words) which had been rated in two sub-lists by either 8 or 9 independent raters for valence, arousal and threat on 9-point scales (anchored by 9 = very exciting, very threatening, or completely happy, and 0 = very calm, very safe, or completely unhappy).

Words selected from this list as 'threat' words had a mean valence rating of less that 3.7 and a mean threat rating of greater than 6.5; 'neutral' words had a mean valence rating of between 4.6 and 5.9 and a mean threat rating of less than 5.2. Words in the threat-neutral pairs different by at least (and preferably more than) 1.71 in mean valence and at least 1.63 in mean threat ratings (mean valence difference was 2.58, mean threat difference was 2.32). Words in neutral-neutral pairs differed by no more than 0.78 in mean valence (mean difference = 0.30) and no more than 0.86 in mean threat (mean difference = 0.21). All word pairs were matched for word length and word frequency (based on norms in Francis & Kucera, 1982).

Word-pair pairings were drawn at random and were the same for all participants. Two sets of words were created, labelled A and B. Order of presentation of these sets was counterbalanced across participants as was block type (structural verses semantic). Thus there were four possible combinations[31] of set and block; the two groups of participants were randomly assigned to these.

Working Memory Task (O-SPAN, Turner & Engle, 1989)

The operation span with words (OSPAN) has been described as a prototypical working memory capacity task (Turner & Engle, 1989). Participants remember words under

[31] Structural-A then Semantic-B; Structural-B then Semantic-A; Semantic-A then Structural-B; Semantic-B then Structural-A.

mental load (performing mathematical operations) and the task is therefore effortful and demanding of controlled attention.

Participants were presented with mathematical operations and to-be-remembered words (e.g. IS (8/4) + 2 = 2 ? BIRD) and responded ‘yes’ or ‘no’ to the mathematical operation (according to whether the correct value is given to the right of the equals sign) as well as remembering the presented words. The number of operation-word strings presented varied from 2-6 and after the set was complete participants were required to write the to-be-remembered words in the exact order on a response sheet. Practice sets were given initially to familiarise participants with the procedure and each set length (2-6) was presented three times in a random order. Span score is the total number of words recalled from correctly recalled sets. So, for example, if a participant correctly recalled all the sets containing 2 operations and one of the sets containing 3 operations, their span score would be 9 (2 + 2 + 2 +3).

Rosen & Engle (1998) excluded participants falling below 85% accuracy on the yes/no responses from their experiment. This was to ensure that participants were memorising the words under conditions of high load and not simply prioritising word encoding at the cost of performing the mathematical operations. However, our participants proved to be poorer at this task and only those falling below 70% were excluded in order to maintain group sizes at a reasonable level.

3.2 Results

All analyses were conducted on SPSS v.14. One participant was excluded from analyses due to a technical error recording response times on the attentional bias task. Additionally, five participants made errors on over 25% of trials in the structural block and were consequently excluded[32] from the analysis. Therefore, N=39 for all analyses (20 participants in low anxiety group, 19 in high anxiety).

3.2.1 Trait measures

Means and standard deviations of trait measures (including transformed outliers[33]) for high and low trait anxious groups are presented in Table 3.1.

Table 3.1: Means (and standard deviations) of trait measures

	High trait anxious		Low trait anxious		F Main effect of anxiety (ANOVA)
Cognitive Avoidance Questionnaire: **TOTAL**	**66.84**	**(16.68)**	**65.00**	**(22.51)**	**0.43**
Cognitive Avoidance Questionnaire: **Thought suppression**	**14.95**	**(2.53)**	**14.75**	**(4.13)**	**0.31**
Cognitive Avoidance Questionnaire: **Thought substitution**	**11.84**	**(4.40)**	**9.80**	**(3.94)**	**2.26**
Cognitive Avoidance Questionnaire: **Distraction**	**15.05**	**(4.25)**	**15.25**	**(6.12)**	**0.11**
Cognitive Avoidance Questionnaire: **Avoid threat stimuli**	**13.58**	**(4.91)**	**13.70**	**(6.46)**	**0.12**
Cognitive Avoidance Questionnaire: **Transform images**	**11.16**	**(3.85)**	**11.50**	**(5.21)**	**0.01**
Penn State Worry Q.	**59.11**	**(8.63)**	**44.20**	**(12.83)**	**18.18*** **

*** significant at p<.001

[32] Participants were not excluded dependent upon error rates in the semantic block since the purpose of this task was to engage participants in semantic processing of the stimuli and it was difficult to establish a right/wrong answer for many of the trials.

[33] Outliers were transformed for the transformation (1 outlier) subscale of the Cognitive Avoidance Questionnaire, and Penn State Worry (1 outlier) by replacing with the next highest score plus one.

An 2x2 MANOVA on all trait measures (independent variables: sex & high/low anxiety) showed a main effect of anxiety group ($F(7,34) = 3.19$, $p<.05$) but no main effect of sex ($F(7,34) = 0.19$, $p=.99$) or interaction between sex and anxiety group ($F(7,34) = 0.47$, $p=.85$). Follow-up 2x2 ANOVAs were conducted on each trait measure (F values for main effects of anxiety are presented in table 3.1) and showed that in addition to trait-anxiety differences the anxiety groups differed only in their reported level of worry.

3.2.2 State measures at baseline

State anxiety at baseline was significantly greater in high anxious participants (mean = 38.47, standard deviation = 10.13) than low anxious participants (mean = 30.50, standard deviation = 6.46), $t(37) = -2.95$, $p<.01$. Depressive symptoms over the previous week, as measured by the BDI, were reported with higher frequency by high anxious (mean = 11.37, standard deviation = 5.36) than low anxious participants (mean = 4.95, standard deviation = 2.96), $t(33.35) = -4.98$, $p<.001$.

3.2.3 Change in state measures (pre- to post- attention task)

Changes in state anxiety were calculated as percentages of baseline scores[34]. High anxious participants (mean = 21.74%, standard deviation = 36.76) reported a non-significant ($t(37) = -1.17$, $p=.25$) 11% greater state anxiety change than low anxious participants (mean = 10.30%, standard deviation = 23.28).

3.2.4 Attention bias assessment task

All reaction times analysed are median response times to screen two. Median reaction times ($t(38) = -1.54$, $p=.13$) and error rates ($t(38)=-1.88$, $p=.07$) were equivalent for

[34] Two outliers transformed by replacing with next highest score plus one.

datasets A and B. Consequently, data from the two datasets were merged for the remainder of analyses.

For each participant, trials with incorrect responses were removed along with trials that contained reaction times longer than 2000ms or shorter than 200ms and, subsequently, trials more than 2 standard deviations from the mean. Median reaction times for each trial type were then calculated. There were no differences between the anxiety groups in structural block error rates (High anxious mean = 5.74 errors, Low anxious mean = 5.50 errors, $t(37) = -0.19$, $p=.85$), semantic block error rates (High anxious mean = 28.05 errors, Low anxious mean = 23.80 errors, $t(37) = -1.62$, $p=.11$), or number of trials excluded as outliers overall (High anxious mean = 8.42 trials removed, Low anxious mean = 7.55 trials removed, $t(26.89) = -0.68$, $p=.50$).

Since no sex effects were found in the previous study (experiments 1 and 2, chapter 2) and the anxiety groups did not have equal proportions of males in this study, sex was not investigated as a factor in reaction time analysis. Means and standard deviations of median reaction times (including transformed outliers[35]) for high and low anxious participants for each trial type in each block of the task are shown in Tables 3.2 and 3.3.

[35] Outliers were transformed for structural engage-move (1 outlier), structural neutral-move (2 outliers), semantic disengage-move (1 outlier), semantic engage-move (1 outlier), semantic neutral-move (1 outlier), semantic disengage-stay (1 outlier), and semantic neutral-stay trials (2 outliers) by replacing with the next highest value plus 0.1.

Table 3.2: Means (and standard deviations) of median reaction times (in seconds) for semantic block.

		Disengage	Engage	Neutral
High Anxious	Stay	**1.03 (0.24)**	**0.96 (0.22)**	**0.88 (0.15)**
	Move	**1.09 (0.15)**	**1.12 (0.17)**	**1.15 (0.26)**
Low Anxious	Stay	**0.99 (0.22)**	**0.93 (0.18)**	**0.87 (0.18)**
	Move	**0.99 (0.15)**	**1.01 (0.17)**	**1.04 (0.20)**

Table 3.3: Means (and standard deviations) of median reaction times (in seconds) for structural block.

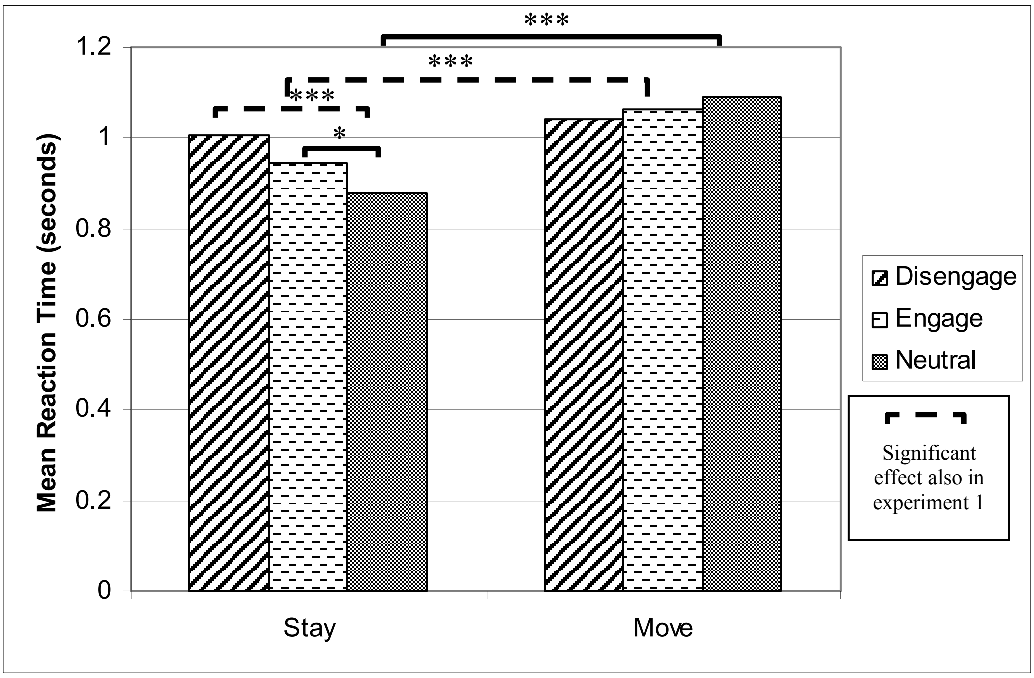
		Disengage	Engage	Neutral
High Anxious	Stay	**0.75 (0.14)**	**0.75 (0.17)**	**0.77 (0.14)**
	Move	**0.91 (0.19)**	**0.90 (0.14)**	**0.90 (0.15)**
Low Anxious	Stay	**0.75 (0.14)**	**0.74 (0.15)**	**0.74 (0.12)**
	Move	**0.90 (0.15)**	**0.87 (0.14)**	**0.90 (0.13)**

Semantic Block: Replication of Chapter 2

A 2 (anxiety group; low, high) x2 (shift; stay, move) x3 (trial type; disengage, engage, neutral) mixed ANOVA on reaction times from the semantic block showed interactions between shift and trial type ($F(2,74) = 7.89$, $p<.01$) and between shift and anxiety group ($F(1,37) = 5.02$, $p<.05$) in addition to the main effect of shift ($F(1,37) = 47.19$, $p<.001$; move trials showing longer reaction times than stay trials). As hypothesised these are the same interactions seen in the semantic task in experiment 1 of the previous chapter.

Follow-up analyses on the shift x trial type interaction (Figure 3.2) revealed that reaction times differed significantly between move and stay neutral trials ($t(42) = 6.22$, $p<.001$), and move and stay engage trials ($t(42) = 5.25$, $p<.001$), but not between move and stay disengage trials ($t(42) = 1.25$, $p=.22$). There were also significant differences between disengage and neutral stay trials ($t(42) = 3.88$, $p<.001$), and engage and neutral stay trials ($t(42) = 2.62$, $p<.05$) but not between disengage and neutral move trials ($t(42) = -1.89$, $p=.07$), or between engage and neutral move trials ($t(42) = 0.22$, $p=.83$). This partially replicates the pattern of results seen in the previous chapter.

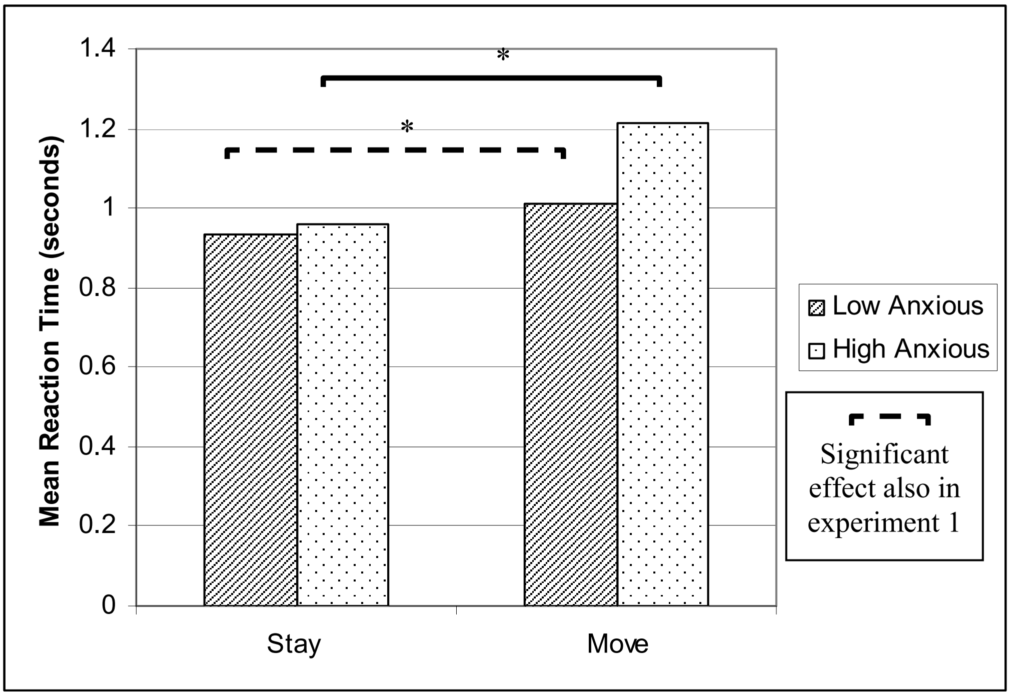
Figure 3.2: Mean median reaction times in the semantic block for each trial type for all participants.



* significant at p<.05
*** significant at p<.001

Follow-up analysis of the shift x anxiety interaction (Figure 3.3) revealed no significant difference between anxiety groups for either move (t(37) = -1.72, p=.09) or stay trials (t(37) = -0.51, p=.61). Both high (t(18) = 2.78, p<.05) and low anxious (t(19) = 2.47, p<.05) participants showed faster reaction times on stay than on move trials. This is unlike experiment 1 in chapter 2 in which only low anxious participants showed a difference between move and stay trials and high and low anxious participants differed in their reaction times on stay trials.

Figure 3.3: Mean median reaction times in the semantic block for move and stay trials for high and low anxious participants.



*   significant at p<.05

Structural Block

A 2 (anxiety group; low, high) x2 (shift; stay, move) x3 (trial type; disengage, engage, neutral) mixed ANOVA on reaction times in the structural block showed a main effect of shift ($F(1,37) = 183.86$, $p<.001$, move trials showing longer reaction times than stay trials) but no other main effects or interactions.

Planned comparisons were carried out to investigate the specific hypothesis that high anxious participants would show increased interference (slowed reaction times) on trials where emotional information was present. A 2 (anxiety group; low, high) x3 (trial type; disengage, engage, neutral) mixed ANOVA (ignoring shift) showed no main effects or interactions.

3.2.5 Working Memory Task

Four outliers were transformed in the working memory span scores by replacing with the next highest score plus one. After excluding participants who did not reach above

70% accuracy on trials (irrespective of whether they got the sum correct, N=24), high anxious participants (mean span = 3.09 words) showed significantly lower working memory span than low anxious participants (mean span = 4.23 words) as hypothesised, $t(22) = 1.14$, $p<.05$. Working memory span did not correlate with any measure of performance on the attention bias assessment task for either of the anxiety groups.

3.3 Discussion

This study aimed to replicate and extend the experiment conducted in the previous chapter. A novel paradigm was used to measure engagement and disengagement biases towards threat stimuli in high and low anxious participants. Participants performed two blocks of the task; one in which they were required to engage with the meaning of the stimuli and one in which they were required to make structural judgements only (and were thereby slowed when they were unable to *inhibit* semantics of the stimuli). Results show a partial replication of previous findings in the semantic block of the attention task including no differences in patterns of biases between high and low trait anxious groups. Hypothesised differences between anxiety groups in the structural block of the task were not found. The anxiety groups differed in their working memory capacity as hypothesised (the high trait-anxious group showed lower working memory capacity than the low trait-anxious group). However, working memory capacity did not correlate with any attention bias measures.

3.3.1 Semantic Block

The semantic block of the present study was intended to replicate the previous study. As in the previous study interactions were found between anxiety group and shifting of location, and between trial type and shifting of location. The main effect of shifting location from the previous study was also evident in the present study. However, unlike in the previous study, present results showed that trials which required participants to move the location of their attention were performed more *slowly* than trials which required maintenance of location (*speeding* on move trials was seen in the previous studies). Additionally, in contrast to the previous findings, no main effects of anxiety group or of trial type were seen in the present study. Follow-up analyses of the interactions found showed that the pattern of results in the present study only partially replicated that of the previous study.

The present study showed differences between move and stay trial reaction times for both high and low trait anxious groups, whilst the previous study showed this difference only for the low trait-anxious group (and an interaction between anxiety group and shift in location). The interaction between anxiety group and location of attention seen in the previous study was suggested to potentially reflect avoidance of previously attended locations in high anxious individuals (not threat-specific) or possibly slowed disengagement amongst low-anxious individuals. The absence of such an interaction in the present study sheds no further light upon these findings.

Engagement Trials in the Semantic Block

In the present study participants showed no difference in reaction times on trials which required engagement with threat words *and* a shift in location of attention, compared to neutral trials. Conversely, the previous study had shown that participants were slower to engage with negative images when they had to shift the location of their attention in order to do so.

Furthermore, the present study found that response times were *slower* on trials requiring engagement with threat (compared to neutral) when *maintenance* of location of attention was required. The previous study had shown no such difference between engage-stay and neutral-stay response latencies.

Previous studies have found *speeded* engagement with negative stimuli in anxious individuals (e.g. Carlson & Reinke, 2008; Koster et al., 2006). These are revealed when reaction times on valid threat trials are shorter than reaction times on valid neutral trials. The study reported in the previous chapter did not show this pattern of results since there was no difference between engage-stay and neutral-stay trials for either the high or low anxiety groups. Furthermore, the present study shows the *opposite* pattern; valid threat (engage-stay) trials show *greater* response latencies than valid neutral (neutral-stay) trials. This result holds for both the high and low trait-anxious groups.

Consequently, findings from the present study failed to support the hypothesis that both high and low trait-anxious participants would be as quick to engage with threat as with neutral items when they were required to *maintain* the location of their attention. However, when they were required to *move* the location of their attention, participants would be slower to engage with threat stimuli than they were to engage with neutral stimuli.

Disengagement Trials in the Semantic Block

Participants in the present study showed slower reaction times on disengage than neutral trials when they had to *maintain* location of attention. However, they showed no difference between disengage and neutral trials when they were required to *move* the location of their attention. In contrast, the previous study had shown a *speeding* on disengage trials when a move in location of attention was required and *slowing* when maintenance of location was required (relative to neutral trials).

Previous research has reported that anxious individuals make slower responses on invalid (probe presented in different location to stimuli) threat-cued trials than on invalid neutral-cued trials (e.g. Fox et al., 2001). These invalid trials can be considered akin to the move trials reported in the present study. The previous study demonstrated the *opposite* pattern of results whilst the present study demonstrated *no difference* between response times on these two types of trials.

No examples could be found in existing literature of paradigms which require disengagement from content but maintenance of location of attention. It is therefore difficult to compare findings from this new task with the existing literature in this respect. It is important to point out though that the present and previous studies revealed the same pattern of *slowing* on disengage trials relative to neutral when maintenance of location of attention was required. However, there are multiple possible explanations for such a finding.

3.3.2 Structural Block

No interactions were seen in the structural block of the present study, only a main effect of shifting location such that trials which required a shift in location of attention were executed more slowly than trials in which participants were required to maintain location of attention. This main effect was in the same direction as the semantic block in this study (but in the opposite direction to the study reported previously). Thus the hypothesis that semantic and structural blocks would differ in their findings is supported.

However, it was hypothesised more specifically that high trait-anxious participants would display longer response latencies for threat stimuli in the structural condition compared with neutral stimuli reflecting increased interference of threat stimuli. This hypothesis was not supported. The present study offered no support for existing evidence that anxious individuals demonstrate increased interference from negative items on some tasks and increased facilitation by negative items on other tasks (Vythilingam et al., 2007).

3.3.3 General Discussion

Broadly the results show that threatening words do not generate the same pattern of attention biases as negative images did in studies reported in the previous chapter. Additionally, when participants are instructed to attend to structural features of stimuli, compared to when they are instructed to engage with semantic content, no such patterns of bias emerge. Consequently, future work on attention biases should pay careful attention to selection of stimuli as well as to task instructions since both are clearly crucial to bias patterns generated.

More specifically, the semantic block of the present study in which participants were asked to make semantic judgements about the word stimuli partially replicates the previous study. Both the present and previous studies revealed the same pattern of *slowing* on disengage trials relative to neutral when maintenance of location of attention was required.

There are two alternative explanations for this finding (in addition to disengagement difficulties) which should be considered. First, it may represent ongoing interference from the previous threat stimuli which is harder to inhibit when location of attention is maintained. Second, it might be a result of avoidance of a location which has previously contained threatening information. A third alternative, that it represents cognitive or motor 'freezing' as a response to threat seems implausible given that no equivalent result was found in move trials.

The present study does not provide evidence for anxiety-group related differences on this task. In fact the present study shows both high and low trait-anxious groups slowing on move trials relative to stay trials. In the previous study this effect was only seen in the low trait-anxious group. Therefore it seems that although high trait-anxious individuals are not slower to move location with images, they are with words. This pattern, however, cannot be related to stimuli valence in any way.

The present study shows a slowing on move trials relative to stay for both the engage trials and the neutral. The previous study showed this slowing only in engage trials. No difference was seen between move and stay disengagement trials in the present study. The previous study had shown speeding on move-disengage trials (relative to stay-disengage trials).

High and low trait-anxiety groups differed in their working memory capacities as hypothesised; high trait anxious participants showed significantly reduced working memory capacity. However, working memory capacity did not correlate with any response latencies meaning that it is not possible to draw conclusions about the role of working memory capacity in response generation on this task.

3.3.4 Limitations

It should be noted that recruitment criteria in the present study did not match those in the previous study. A post-recruitment median split of participants according to trait anxiety score was utilised in the present study whilst in the previous study only upper and lower quartiles of respondents were invited to take part. This may have meant that the two groups in the present study were not sufficiently different from each other to show differential attentional bias patterns. However, the previous study reported patterns of attentional bias which were general across all participants and there seems to be no reason why these would not also be present in the sample in the current study.

Two important features of the stimuli were altered in the semantic block of the current study compared to the study reported previously. First, word stimuli were used instead of images. Word stimuli have been used widely and have shown attention biases in high trait anxious individuals (e.g. Edwards et al., 2006; MacLeod et al., 1986; MacLeod & Hagan, 1992; MacLeod et al., 2002). However, emotional words do not show the same interference effects for anxious individuals as emotional faces do in the emotional Stroop task (Reinholdt-Dunne et al., 2009). Moreover, several researchers have pointed out that threatening words are likely to be more frequently used by anxious individuals and consequently more familiar (Bar-Haim et al., 2007; Bradley et al., 1997b; McNally et al., 1990; Fox et al., 2002). Therefore, bias effects seen with words may represent familiarity effects rather than attention biases per se. It is perhaps not surprising therefore to find different results from words and images. Given that the paradigm reported here involves very conscious processing, it is possible that the familiarity of the word stimuli in the present study allowed individuals to employ well-practiced emotion regulation strategies and thus inhibit any avoidance-like behaviour.

Second, the stimuli used in the present study were threatening instead of negative. Whilst evidence has been shown for delayed disengagement from negative stimuli amongst high-anxious individuals (Spielberger et al., 1983), a large amount of attention bias research has employed threatening stimuli (usually words or angry or fearful faces). It seems logical therefore that threat stimuli would be required to see engagement biases. Consequently, the lack of engagement biases in high compared to low trait-anxious participants which were seen in both the previous and present studies can now be relied upon with more confidence.

3.3.5 Conclusions

The present study failed to fully replicate the findings of the previous study. Threatening words were used as stimuli and did not generate the same pattern of attention biases that negative images had in the previous study. This may reflect well-rehearsed strategic behaviour for dealing with linguistic stimuli, or may reveal a difference between generalised patterns in processing threat as opposed to negative stimuli.

Additionally, in the present study participants were instructed in one block to attend to structural features of stimuli, instead of engaging with semantic content, and different patterns of biases emerged. Further work comparing the effect of these two instructional sets on biases would be of interest.

Chapter 4: Individual differences in non-conscious evaluation of faces

Preferential processing of important stimuli is a necessary feature of limited-capacity processing. However, 'importance' varies between individuals and also according to context and task demands; *anxious* individuals attend to *threat* stimuli preferentially (Bar-Haim et al., 2007) whilst heavy drinkers show a bias towards alcohol cues (Field & Powell, 2007). How closely stimuli must match individuals' concerns in order for this bias to be evident is unclear and, for example, there is some debate in the literature as to whether patients with posttraumatic stress disorder (PTSD) only show biases for stimuli which are specifically related to their traumas or whether a more general threat-bias is evident (Buckley et al., 2000). However, it seems unlikely that each of these types of bias represents a unique system at work and, consequently, threat bias in anxious individuals may depend on systems which are ubiquitous but differentially applied in non-anxious populations. As such it is useful to the investigation of threat biases to consider individual variations in the processing of stimuli which have wider significance (e.g. socially relevant stimuli). Moreover, triggering traumatic events in PTSD and threats in general are frequently interpersonal or social in nature meaning that processing of socially-relevant stimuli has particular relevance for anxiety disorders generally and PTSD more specifically.

Inferences made about faces on social qualities such as trust, competence and friendliness are extremely fast and quantitatively replicable across time (Todorov et al., 2008b). Moreover, these evaluations are predictive of important social outcomes such as election results (Todorov et al., 2005). Although not necessarily accurate, a recent study suggested that observer evaluations may usefully predict the face owner's social behaviour too: more trustworthy-looking males were more likely to reciprocate favours in a social economic game that called for mutual trust and cooperation (Stirrat & Perrett, 2010). It has been proposed that two major axes, trustworthiness and dominance, predominantly characterise the social dimensions of face evaluation (Oosterhof & Todorov, 2008).

Whether social evaluation of faces is restricted to conscious appraisal or happens at a preconscious level is unknown. Extensive behavioural and neurophysiological evidence suggests that processing of faces (as a category of visual object) is not restricted to conscious awareness (Jiang et al., 2007a; Sterzer & Rees, 2008; Sterzer et al., 2009). The case for preconscious face processing is perhaps strongest (and most popularized) for affective expressions such as fear (Adams et al., 2010; Alpers & Gerdes, 2007; Jiang & He, 2006; Morris et al., 1998; Whalen et al., 2004; Yang et al., 2007; Yoon et al., 2009). The success of this line of research has led to the proposition of a dedicated, automatic subcortical neuronal mechanism involving the human superior colliculus and amygdala for “quick and dirty” visual evaluation of evolutionarily relevant facial expressions (Morris et al., 1999; Morris et al., 2001; Vuilleumier, 2005). This evolutionary vigilance account posits that preconscious face processing promotes survival by contributing to rapid, albeit coarse, detection of threatening situations. Moreover, it follows from the anxiety literature outlined in previous chapters that individual differences may exist in preconscious processing of evolutionarily important facial traits, just as they do with affective facial expressions. Individual variation in pre-conscious processing may also have implications for conscious experiences of faces (and consequently of people).

Two independent studies (Jiang et al., 2007a; Yang et al., 2007) recently introduced a novel method for assessing preconscious face processing. Jiang and colleagues (2007a) presented an upright or inverted face to one eye and rendered the face invisible by simultaneously presenting rapidly flashing high contrast masks to the other eye (an interocular suppression technique known as continuous flash suppression, CFS). To obtain a measure of preconscious face processing they measured the time it took for a suppressed face with gradually increasing contrast levels to break through the suppression and become visible. Upright faces broke through CFS faster than inverted ones indicating that preconscious face processing distinguishes between holistic facial configurations. Employing a very similar method, Yang and colleagues (2007) showed that fearful faces break through interocular suppression faster than happy and neutral faces lending support to the vigilance hypothesis introduced above. This paradigm provides a good opportunity to test predictions of the vigilance hypothesis about the preconscious social evaluation of faces. One prediction is that faces associated with stronger threat, i.e. more dominant and less trustworthy faces, should break through suppression faster than neutral faces.

In contrast, some studies employing face adaptation paradigms have cast doubt on the notion that higher level characteristics of faces can be coded pre-consciously. Adaptation paradigms present one variant of a stimulus (e.g. an *angry* face) and measure response to a subsequent target stimulus (e.g. a *neutral* face). Recent work has utilised CFS to present the adaptation stimulus with and without participants' conscious awareness. By displaying an adaptation stimulus at a low contrast whilst a flashing high contrast mask is presented to the other eye, the adaptation stimulus can be present on the experimental display screen for extended periods but not visible. Adaptation to facial identity (Moradi et al., 2005), gender and race (Amihai et al., 2010) have only been observed when the adaptor faces are consciously perceived.

Interestingly, "invisible" (or faces of which there is no conscious awareness) adaptor faces can induce adaptation to gender (Shin et al., 2009) and facial expression (Yang et al., 2010) but only if spatial attention is directed to the location of the invisible adaptor. In the absence of any explicit spatial attentional cues, the results from face adaptation literature (Amihai et al., 2010; Moradi et al., 2005) would restrict higher level social evaluation of faces to conscious perception (but see also Adams et al., 2010 for a more recent report of the opposite finding). In sum, the contradictory findings about preconscious high- level face perception show clearly that preconscious evaluation of faces on social dimensions is an open and highly relevant question.

Individual differences in extraction of meaning from faces are well established (e.g. See Little et al., 2011 for a recent review of observer differences in facial-attractiveness perception) and variation in pre-conscious processing of emotion in faces is proposed by many (e.g. Etkin et al., 2004; Pessoa, 2005). Using CFS, observer differences have been shown in pre-conscious *image* processing. A variant of the Posner cueing task (Posner, 1980), with stimuli presented under conditions of intraocular suppression, has yielded interesting results. Not only can erotic images presented behind CFS noise patches attract and repel attention in this paradigm, but whether observers orient towards invisible images or avoid them depends upon both the gender of the models and observers' sexual preferences (Jiang et al., 2006); Heterosexual males directed attention towards erotic images of females and away from males whilst homosexual males and heterosexual females showed the reverse pattern. Moreover, these effects are evident despite observers being unaware of the presence of these images. Such evidence for individual differences in processing priorities lends support for the supposition that there may be variation between observers' speed at bringing important stimuli such as faces to awareness. Indeed, recent work has shown that elevated trait anxiety is associated with an increased tendency to perceive angry and fearful faces and a decreased tendency to perceive happy faces (Gray et al., 2009). Consequently, one hypothesis in the present study is that individual differences in the time taken for stimuli to reach awareness will be related to individual differences in observers' traits.

In the series of experiments in the present study, the following were investigated: (1) whether evaluation of faces on social dimensions extends to preconscious perceptual processing; (2) to what extent these preconscious processes are observer-specific; and (3) whether observer-specific differences in pre-conscious threat processing could underlie a mental health disorder known to be associated with threat-vigilance (posttraumatic stress disorder).

The 2-dimensional trust-by-dominance face space (Oosterhof & Todorov, 2008) provides a well-controlled quantitatively validated stimulus repertoire of faces that allowed manipulation of these two social dimensions independently (see Figure 4.1). To probe preconscious face processing, in experiment 1, faces were rendered invisible by interocular suppression and measured the time taken by the face to break into awareness (Jiang et al., 2007a; Yang et al., 2007). Experiment 2 was conducted as a test of whether the results of experiment 1 could be due to generalized differences in conscious responses to threatening faces. Experiment 3 assessed observer-specific effects on preconscious perception and tested whether self-reported personality traits were related to individual variability in preconscious social evaluation. Finally, experiment 4 investigated whether a patient group who report having special vigilance for potential threat (American Psychiatric Association, 2000), who show pervasive interpersonal *dis*trust (Cias et al., 2000), and for whom other paradigms have identified threat bias for non-consciously exposed stimuli (Harvey et al., 1996), would show distinct patterns of behaviour in this preconscious perception paradigm.

4.1 Experiment 1: Continuous Flash Suppression of socially relevant faces

This experiment aimed to investigate whether evaluation of faces on social dimensions reported in the literature (Todorov et al., 2005; Todorov et al., 2008b; Todorov, 2011) extends to preconscious perceptual processing. Based upon the vigilance hypothesis (Morris et al., 1999; Morris et al., 2001; Vuilleumier, 2005) it was hypothesised that faces which are associated with stronger threat, i.e. more dominant and less trustworthy faces, would break through suppression faster than neutral faces.

4.1.1 Methods

Participants

Twenty seven participants (11 females) took part in Experiment 1. All participants had normal or corrected-to-normal vision and ranged in age from 18 to 29 years (mean = 22.0 ± 3.1yrs). Participants gave informed consent according to the guidelines of the local research ethics committee. Four participants were excluded from the analysis; two decided to leave the experiment in the middle, one had forgotten his glasses and could not see the faces clearly, another participant revealed upon debriefing that he had resorted to blinking his CFS eye selectively to do the task. Consequently, N=23 for all analyses.

Display apparatus and stimuli

The experimental paradigm was programmed using the Cogent Toolbox (Cogent 2000 v1.25, www.vislab.ucl.ac.uk/cogent.php/) for MATLAB version 7.2.0.232 (R2006a, Mathworks Inc). Stimuli were presented on a Sony Trinitron GDM-F520 monitor (800 x 600 at 85 Hz) and viewed through a mirror stereoscope mounted on a head and chin rest, at a viewing distance of 65.5cm. The images presented to the two eyes were displayed side-by-side on the monitor, each with a tile frame surround (11.77° visual angle), upon a uniform grey background (background luminance = 65 Cd/m^2). A central white fixation cross (0.6° visual angle) was presented to each eye. Optimal fusion of the two images was ensured prior to commencing each experiment. Behavioural testing was carried out in a dark and quiet room.

Emotionally-neutral Caucasian face images were generated using customized version of the Facegen Modeller programme (Figure 4.1; http://facegen.com). This customized software version provides two orthogonal parameters that allowed manipulation of perceived trustworthiness and dominance based on an extensively validated model (Oosterhof & Todorov, 2008)[36]. Trustworthiness and dominance of the same face identity were systematically varied in 7 steps of 1 standard deviation (-3,-2,-1, 0,+1,+2,+3) straddling the neutral. The result was a set of 49 faces covering all possible combinations of trust and dominance in the employed range.

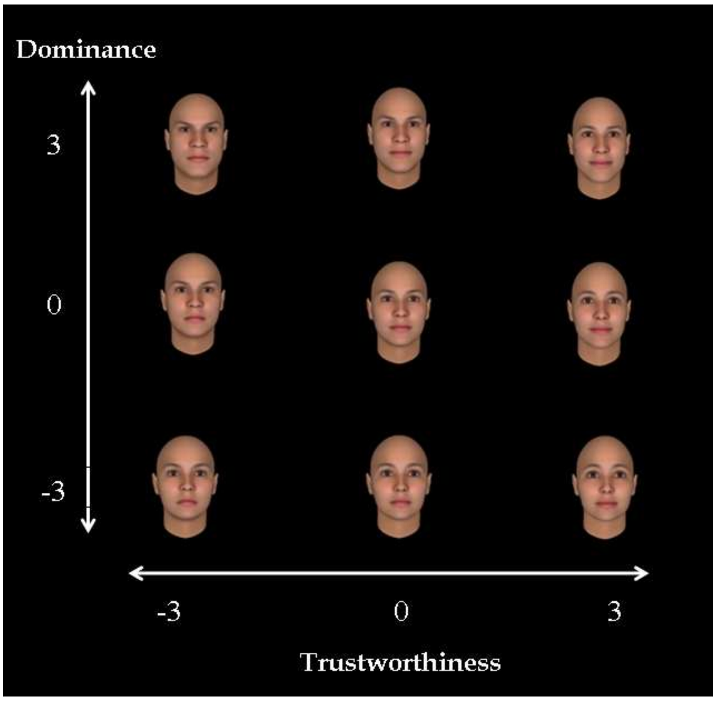


Figure 4.1: Two dimensional (Trust x Dominance) space of social evaluation of faces.

[36] Oosterhof & Todorov's (2008) model of face evaluation is derived from a principle components analysis of trait judgements made by 327 participants about photographs of emotionally neutral faces; analysis of trait ratings revealed trustworthiness and dominance were the two traits which accounted for the greatest proportion of the variance in ratings. Based upon these ratings a statistical model was built to represent how faces vary in trustworthiness and dominance. Emotionally neutral faces were generated from this model, each with seven versions on the trustworthiness and dominance axis. Participants were asked to judge these faces on trustworthiness and dominance and these ratings tracked the traits predicted by the model.

Procedure

The experimental paradigm is shown in Figure 4.2. Each trial started with presentation of Continuous Flash Suppression (CFS) to the non-dominant eye at full contrast. CFS consisted of dynamic noise patterns (frequency 10Hz) generated by superimposition of shapes of random size and color at maximum contrast (Bahrami et al., 2007; Bahrami et al., 2008b; Bahrami et al., 2008a; Bahrami et al., 2010; Jiang et al., 2006; Jiang et al., 2007a; Jiang et al., 2007b; Tsuchiya & Koch, 2005). While CFS was presented to the non-dominant eye, the test face was presented on a black background to the dominant eye at a location 1cm (~0.7° visual angle) left or right of centre. The contrast of the test face was ramped up gradually from 0% to 100% during the initial 2200ms of the trial and subsequently remained constant (as per Jiang et al., 2007a) until the participant responded or the trial terminated. Participants were instructed to press a button (C or Z button) on a standard keyboard as soon as they were confident that the suppressed face was either on the left or on the right side of the central fixation. Speed and accuracy were both emphasized. Thus, correct responses provided a measure of the time (from onset of stimulus presentation to button press) taken by the suppressed stimulus to break through the CFS and emerge into awareness. This measure, which I call time-to-emerge (T2E) was the main dependent variable for the face stimulus. If the face did not break through CFS or the participant did not respond after 10 seconds, the trial terminated automatically and was excluded from analysis. After every correct response, participants were asked to use the mouse pointer to click on the part of the face that had emerged through CFS first. The data from this task were corrupted by a programming error and are not reported here.

Participants completed a total of 490 trials (10 blocks of 49 trials each), with each of the 49 face stimuli presented a total of 10 times (once in each block). Each participant started with a practice block of 49 trials identical to the rest of the experiment, except that the eye presented with the face stimulus was randomized for each trial. This practice served the dual purpose of familiarizing participants with the paradigm and defining eye dominance. In a pilot test prior to the experiment, it was observed that when presenting the suppressed face to the non-dominant eye, very occasionally the face did not break through the CFS even after 10 seconds. Thus presenting the suppressed face to the non-dominant eye or indeed randomizing the suppressed eye, led to considerable variability across trials and many trials had to be excluded. Using the practice block to determine the dominant eye gave a consistent criterion for avoiding this undesirable variability. The dominant eye was defined as the eye for which the suppressed face broke through the CFS and emerged to consciousness more quickly. Throughout the main experiment, the suppressed stimulus was only presented to the dominant eye.

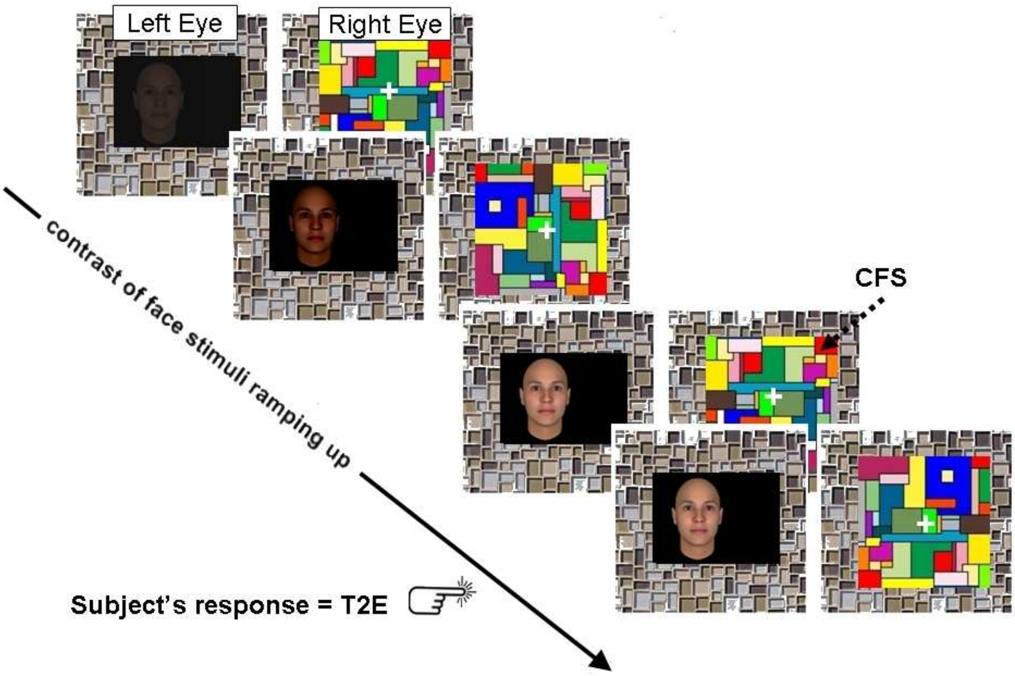


Figure 4.2: The sequence of events in a single trial in experiment 1.
T2E = Time-to-emerge. CFS = continuous flash suppression.

Data preparation

Substantial between-participant variability was observed for the T2E measure; across all experiments, mean values for T2E ranged from 0.63 to 4.63 seconds. For this reason, within each participant, mean T2E was first calculated for each condition of interest. These participant-specific mean values were then normalised by calculating Z-scores across the levels of the condition under study. Normalized T2E values were employed in the subsequent, group level analyses[37]. A 2 (sex) x7 (trust levels) x7 (dominance levels) ANOVA showed no main effect of sex ($F(1,21) = 0.92$, $p=.35$) and no

[37] One outlier at trust level -2, dominance level +1 was transformed by replacing with the next nearest value plus one. All other levels of each factor met parametric assumptions.

interactions between sex and the other factors (Trust: $F(6,126) = 0.76$, $p=.60$; Dominance: $F(6,126) = 1.21$, $p=.31$); consequently, data were collapsed across sex for the remainder of analyses. The distribution of the raw (non-normalized) effects sizes are reported in experiment 3 (see Figure 4.4) where the relationships between T2E and individual differences are discussed.

4.1.2 Results and discussion

A two-way repeated-measures ANOVA with dominance and trust as factors (7 levels for each factor) revealed a main effects of both dominance ($F(6,132) = 5.02$, $p<.001$; Figure 4.3A) and trust ($F(6,132) = 2.47$, $p<.05$; Figure 4.3B). The interaction between the two factors was not significant ($F(36,792) = 0.98$, $p=0.5$). As shown in Figure 4.3, for the dominance factor the variance consisted of a significant linear ($F(1,22) = 23.97$, $p<.001$) as well as a significant quadratic component ($F(1,22) = 6.93$, $p<.05$). For the trust factor, however, only the quadratic component was significant ($F(1,22) = 7.79$, $p<.05$).

Posthoc comparisons revealed that the main effect of dominance in experiment 1 comprised significantly longer T2E for the most-dominant ($t(22) = 6.56$, $p<.001$) and second-most dominant (+2 st. dev.) faces ($t(22) = 2.33$, $p<.05$) when compared to the neutral-dominance faces. Furthermore, consistent with the quadratic trend reported above, the least (-3 st. dev) and the most trustworthy faces took significantly longer time to break through consciousness compared to neutral faces (for untrustworthy faces: $t(22) = 3.18$, $p<01$; for trustworthy faces: $t(22) = 2.07$; $p<.05$).

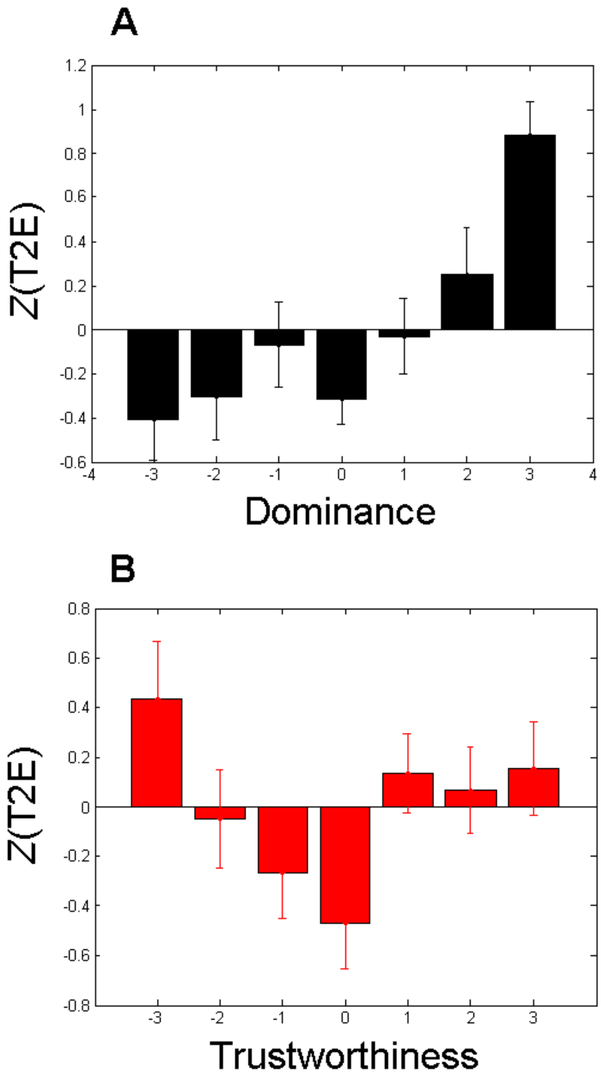


Figure 4.3. Experiment 1 results. Normalized values of Time-to-emerge (T2E) averaged across subjects (N=23) are plotted against dominance (A) and Trustworthiness (B) values of the suppressed faces. Error bars represent the standard error of means.

These results clearly demonstrate that evaluation of faces on social dimensions extends to preconscious perceptual processing. Moreover, they contradict the predictions of vigilance hypothesis by showing that the most threatening faces i.e. the most dominant and least trustworthy faces broke through interocular suppression significantly more slowly than the neutral faces.

4.2 Experiment 2: Differentiating conscious and pre-conscious processes

The results of experiment 1 are open to an important alternative interpretation: the observed results may not in fact show a difference in duration of suppression under CFS but, instead, could reflect the fact that observers were generally slower to respond to more threatening faces (*after* the face had broken through CFS). This view predicts that a similar behavioural result would be observed even if the faces were presented consciously (i.e. without being suppressed behind CFS). Experiment 2 tests the hypothesis that a general threat-induced slowing of motor response is responsible for the results seen in experiment 1.

Participants in experiment 2 performed trials in which face stimuli were suppressed from awareness (like in experiment 1), as well as trials in which the faces were never suppressed (binocular presentation of the face stimulus on top of the Mondrian colour-grid). It is hypothesised that if the results in experiment 1 were due to a slowing of the motor response in the presence of threat, participants in experiment 2 would show the same pattern of results to faces varying in trustworthiness and dominance traits as have been seen for pre-conscious processing. If, however, the results of experiment 1 truly do reflect pre-conscious processing effects then participants in experiment 2 should show this trait-related slowing only under conditions of preconscious viewing and not when stimuli are available to conscious awareness.

4.2.1 Methods

Participants

Twenty one participants (16 females) took part in Experiment 2. All participants had normal or corrected-to-normal vision and ranged in age from 18 to 35 years (mean = 22.4 ± 4.4yrs). Participants gave informed consent and the experiment was approved by the local research ethics committee.

Display apparatus and stimuli

Display properties were identical to Experiment 1. For the face stimuli, given that in Experiment 1 the most prominent effects were found in the extremes of trust and dominance scales, here, manipulations of trustworthiness and dominance were restricted to (-3, 0 , +3) standard deviations on each axis, producing a set of 9 faces covering the extremes as well as the middle point of each axis.

Procedure

One half of the trials (randomly interleaved) were identical to Experiment 1. In the other half, the same face stimuli were presented to *both* eyes and *on top* of the CFS stimulus leading to conscious, unsuppressed perception of the faces. The experiment consisted of 15 blocks of 18 trials. Each face stimulus was repeated twice in each block (once suppressed by CFS and once not). The participant's task was to decide whether the face was on the left or right side of the fixation point by pressing the same keyboard buttons as in experiment 1.

4.2.2 Results and discussion

The experimental manipulations consisted of two social (3 levels of dominance and 3 levels trust) and one nonsocial (2 levels of visibility) factors (see Figure 4.4). A three-way (dominance x trust x visibility) repeated-measures ANOVA was applied to the normalized correct T2E. A highly significant main effect of visibility was found ($F(1,20) > 1000$, $p<0.001$) reflecting the trivial fact that response times were much faster to unsuppressed faces. More importantly, the main effect of dominance (Figure 4.4A) was significant ($F(1,20) = 6.27$, $p<.01$). A significant interaction ($F(2,40) = 4.88$, $p<.05$) was also observed between dominance and CFS indicating that only in the suppressed condition did the highly dominant faces take longer to break through CFS.

Posthoc comparison showed that T2E was significantly longer ($t(20) = 3.45$, $p<.01$) for dominant than neutral invisible faces thus replicating the results of Experiment 1. The main effect of trust was also significant ($F(2,40) = 4.83$, $p<.05$). A trend was observed for interaction between trust and suppression which was marginally significant (F(2,40) = 2.65, p=.08). A significant quadratic component was observed for trust (F(1,20) = 13.48; p<.01) which interacted significantly with visibility (F(1,20) = 6.87, p<.05). Replicating experiment 1, T2E was significantly longer both for untrustworthy (t(20) = 2.31, p<.05) and trustworthy faces (t(20) = 3.04, p<.01) compared to the neutral invisible faces. Neither the 2-way interaction between trust and dominance (p=.36) nor the 3-way interaction (p=0.17) were significant.

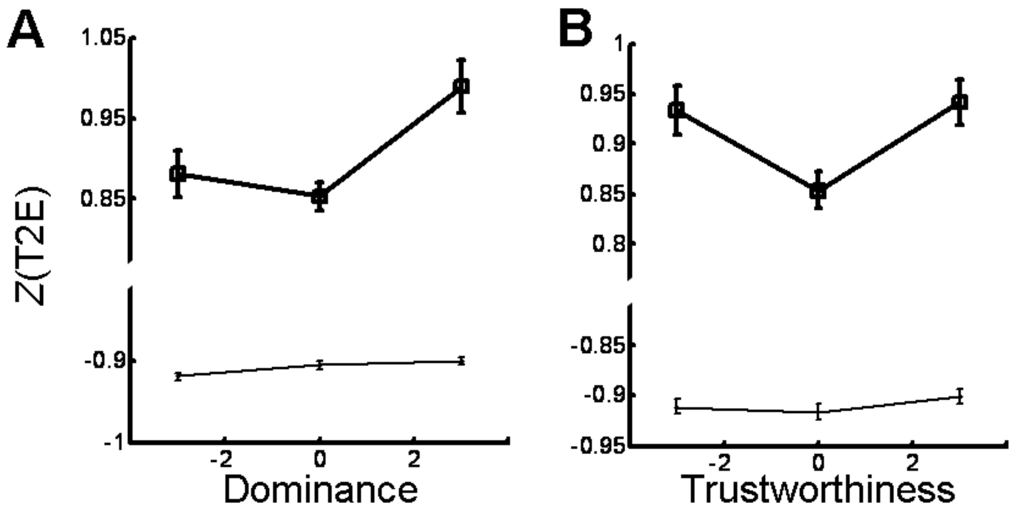


Figure 4.4. Experiment 2 results. Each plot shows the average normalized Time-to-emerge (T2E) (*N*=21) plotted against dominance (A) and Trustworthiness (B) of the suppressed faces. The impact of each social dimension on responses is plotted separately (collapsing on the other dimension). Thick and thin lines correspond to suppressed and visible faces, respectively. Error bars represent standard error of mean.

These results replicated the findings of Experiment 1 in the pre-conscious viewing (CFS) condition in a new group of observers and showed that under conscious viewing conditions, reaction times were not modulated by social valence of the faces. The positive evidence from the significant interactions between dominance and visibility and a similar trend for trust and visibility speak against a general threat-induced slowing of motor responses.

4.3 Experiment 3: Individual differences in pre-conscious processing of faces

Individuals differ in their inclination to trust others and these trait variations may have correlates in individual differences in face perception. Consistent with this proposition, when an affective and a neutral face compete for initial dominance in binocular rivalry, high trait-anxious observers more frequently report initial perception of negative expressions (i.e fearful and angry faces Gray et al., 2009). This suggests that variation in observers' personality traits and individual differences in preconscious face processing (i.e. neural events *before* the initial dominance) may be closely linked.

To test the hypothesis that preconscious perception of trust and dominance are linked to relevant traits of observers, participants from both of the preceding experiments were asked to complete three validated questionnaires to assess propensity to trust, frequency of submissive behaviours, and social anxiety. The questionnaires were specifically selected to assess individual differences in personality traits that may relate to the social evaluation of faces along the axes of trust and dominance.

The Propensity to Trust Survey (Evans & Revelle, 2008) and the Submissive Behaviour Scale (Allan & Gilbert, 1997) were selected as the most well-validated questionnaires available which assessed individuals' tendency to engage interpersonally in a trusting and submissive way respectively. Consequently, it was hypothesised that; 1) an individual's speed at preconsciously processing untrustworthy faces (compared to neutral) would be related to their propensity to trust people; and analogously 2) that individual variation in preconscious processing of dominant faces would be related to reported frequency of submissive behaviour.

The brief version of the Fear of Negative Evaluation questionnaire (an assessment of level of trait social anxiety; Leary, 1983) was also administered. The vigilance hypothesis posits that preconscious face processing promotes survival by contributing to rapid detection of threatening situations. As such, it was hypothesised that individuals who reported higher levels of social anxiety would show greater vigilance (speeded preconscious processing of these faces compared to neutral) for faces which were high in traits which might indicate threat (dominant and untrustworthy faces).

4.3.1 Methods

Participants

Participants from experiments 1 and 2 as well as twenty-two participants (15 females) from a further study which looked at face inversion effects under CFS (results not reported here), were invited via email to complete three questionnaires online; twenty-two participants responded. In order to increase the sample size for the correlational analysis, an abridged version of experiment 1 was conducted with 28 additional participants reaching a total of 50 participants. The trials in this experiment were identical to both the trials in experiment 1 and those in the upright condition of experiment 2. Participants located the face relative to the fixation point (left vs. right). After eye-dominance was established during the practice block, each participant completed a total of 288 trials (8 blocks of 36 trials each) with each of the 9 face versions used in experiment 2 presented a total of 32 times (4 repetitions in each block) to the dominant eye.

Procedure

Participants were invited via email to complete the three questionnaires online. Invitations were sent to participants from experiments 1 and 2 approximately 4 months after completion of the behavioural testing sessions; additional participants recruited were invited to complete questionnaires approximately 1 week after their testing session. Questions were presented and responses recorded using Opinio survey software (www.objectplanet.com/opinio/).

Materials

1. *Submissive Behaviour Scale (SBS)*

The SBS is a 16 item self-report measure of general submissive social behaviour (Allan & Gilbert, 1997; adapted from Buss & Craik, 1986). Participants are required to indicate how often they behave in a variety of submissive ways; each of 16 items is rated on a 5-point scale from "never" to "always", resulting in scores which range from 0 to 64, with higher scores indicating more frequent submissive behaviour. The SBS shows internal validity and test-retest reliability (Allan & Gilbert, 1997). Cronbach's α in experiment 3 was 0.92.

2. *Propensity to Trust Survey (PTS, trust items only)*

Seven items loading most heavily onto the trust factor (Evans & Revelle, 2008) were taken from the full PTS (a 21 item questionnaire which assesses two dimensions: interpersonal trust and trustworthiness). Participants rate items on a 6-point scale according to the extent to which they consider that the items are descriptive of them ("strongly inaccurate" to "strongly accurate"); higher scores indicate a greater inclination to trust others. The full PTS has been shown to have good internal reliability and external validity (Evans & Revelle, 2008). Cronbach's α in experiment 3 was 0.71.

3. *Fear of Negative Evaluation (brief version, FNEB)*

The FNEB is a commonly used 12-item assessment of social anxiety. Participants are required to indicate on a 5-point scale how characteristic of them certain social anxiety behaviours are ("not at all", "slightly", "moderately", "very", "extremely"). Scores range from 12-60 with higher scores indicating elevated levels of social anxiety. The FNEB has been shown to be reliable (Leary, 1983) and has been validated both with patients (Collins et al., 2005) and non-clinical samples (Watson & Friend, 1969). Cronbach's α in experiment 3 was 0.76.

Data preparation

For each participant who completed the questionnaires, two psychophysical measures of preconscious social evaluation were calculated using the raw, non-normalized T2E data:

$$\text{Dominance avoidance} = T2E_{+3dom} - T2E_{neutral},$$
$$\text{Untrustworthiness avoidance} = T2E_{-3trust} - T2E_{neutral}$$

Scores from the self-report questionnaires were then correlated with these psychophysical measures[38] of preconscious perception of dominance and trust.

4.3.2 Results and discussion

Self-reported submissive behaviour was positively correlated with dominance avoidance (Pearson's r = 0.29, $p<.05$; Figure 4.5A). The more dominant faces remained suppressed for longer in more submissive participants. Submissiveness did not predict the variation in avoidance of untrustworthy faces ($p>0.2$; Figure 4.5B). There was a strong inverse correlation between self-reported propensity to trust and both dominance avoidance (Pearson's r = -0.42, $p<.01$; Figure 4.5C) and untrustworthiness avoidance (Pearson's r = -0.39, $p<.01$; Figure 4.5D). Distrusting people (i.e. those reporting that they were unlikely to trust others easily) were slower to become aware of the masked untrustworthy as well as the dominant faces relative to the neutral. The degree of social anxiety, as measured by fear of negative evaluation, did not relate significantly to either of the behavioural indices ($p>0.23$; Figure 4.5E; $p>0.69$; Figure 4.5F).

[38] Outliers were replaced with the nearest value plus one for the dominance avoidance (4 outliers) and trust avoidance (3 outliers) variables.

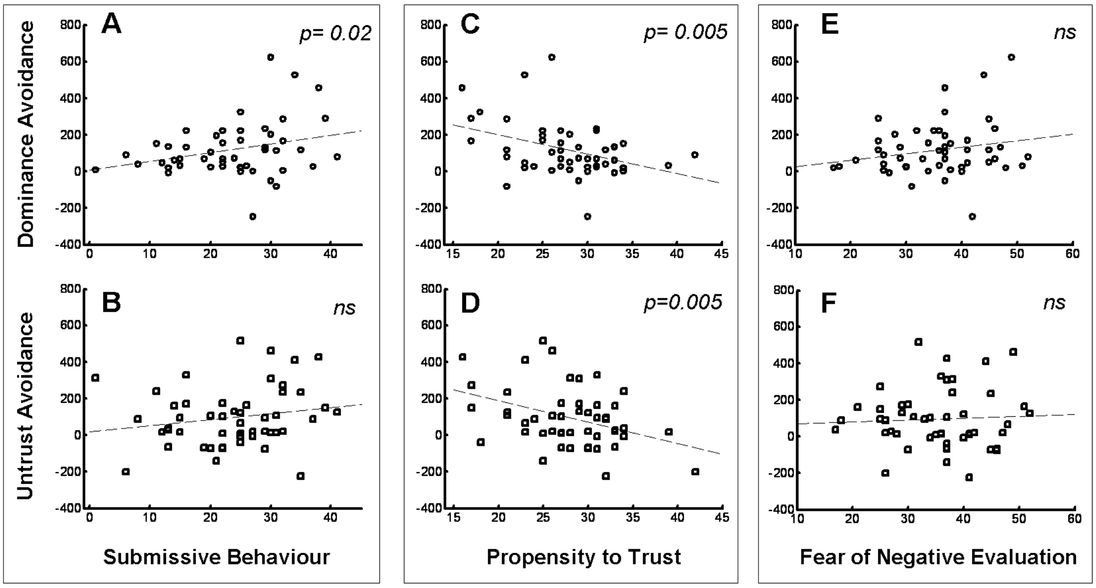


Figure 4.5. The relationship between self-reported personality traits of participants (x-axis) and psychophysical performance (y-axis) *(N=50)*. Each plot shows size of dominance avoidance effect (A, C, E) or size of untrustworthiness avoidance effect (B, D, F) plotted against scores of personality trait questionnaires. Each subject is represented by one datapoint and dashed lines represent lines of best fit.

The behavioural data for preconscious perception of trust showed a quadratic trend: shortest T2E was observed for neutral face while both trustworthy and untrustworthy faces took longer than neutral to emerge into awareness. Importantly, trust avoidance ($T2E_{+3trust} - T2E_{neutral}$) did not show any significant correlation with any of the three personality traits (all p>0.3, Pearson's $r < 0.15$). It is emphasized, however, that the main hypothesis connecting personality traits to preconscious social evaluation was mainly concerned with threatening (untrustworthy, dominant) faces which correspond to the main results described in this section (Figure 4.5).

These results suggest that self-reported social trait characteristics are related to the individuals' preconscious perception of socially relevant visual information. However, some cautionary notes must be made; within the psychophysical task, the two measures of preconscious avoidance (i.e. dominance and untrustworthiness) were clearly correlated (Pearson's $r = 0.32$, $p<.05$). Moreover, a strong, hitherto unreported negative correlation was observed between submissiveness and interpersonal trust scores (Pearson's $r = -0.60$, $p<.001$): participants who reported being more open to trusting others also reported less likelihood of submissive behaviour. The implications of this finding which, to my knowledge, has not been reported before are beyond the scope of the current study but likely reflect the role of submissive behaviour as a defensive strategy in situations where interpersonal trust is low. However, these two *internal* correlations (one between the two psychophysical measures and the other between the main personality measures) complicate the interpretation of *how* the observer-specific traits relate to preconscious perception which is, indeed, a very interesting question for future research. Nonetheless, the main message from the findings, i.e. that observer-specific-traits *do* relate to preconscious perception of social categories is not affected by the internal relationships within each method for at least two reasons: the psychophysical task was an incidental (left/right) judgement which was entirely orthogonal to the social categories assigned to the faces and the questionnaire responses were obtained with substantial (at least 1 week) time difference from the psychophysical testing.

4.4 Experiment 4: PTSD and pre-conscious processing of faces

Experiment 3 demonstrated that individual differences in trait characteristics were correlated with inter-individual variability in preconscious perception of faces. Experiment 4 aims to extend this finding and determine whether anxiety disorder symptomatology might be related to preconscious perception of faces.

A preconscious bias towards threat items amongst anxious individuals (including angry or fearful faces) is assigned both causative and maintaining roles in key cognitive theories of anxiety (see Bar-Haim et al., 2007 for a review of evidence). Work to date has utilised backwards masking paradigms in order to prevent stimuli from entering consciousness (e.g. Edwards et al., 2006; Mogg et al., 1993; Mogg & Bradley, 2002). In these paradigms stimuli are presented for only very short exposure durations and followed immediately by a visual mask which prevents the stimulus from reaching awareness.

CFS does not suffer the time limitation of backwards masking[39]. Since backwards masking can render stimuli invisible for only short durations it, therefore, lends itself well to the investigation of vigilance but not of avoidance. Consequently, the study of non-conscious processing in anxiety may have been limited by the paradigms used and evidence of pre-conscious *vigilance* may be only part of the story. The use of CFS with anxious populations allows for investigation of hypothesised differences in pre-conscious disengagement or avoidance processes (Fox et al., 2001; 2002).

Research on pre-conscious processing in anxiety has focussed on valenced stimuli; to my knowledge no work on anxiety has explored preconscious processing of non-expressive faces varying in social traits. Work using expressive faces has been open to the criticism that effects observed are a result of low-level feature detection and not the product of processing of higher-level meaning such as valence. Consequently, using

[39] Backwards masking and continuous flash suppression effects have been proposed to reflect the operation of different neural pathways (Almeida et al., 2008). Backwards masking is hypothesised to allow information to reach both ventral and dorsal visual pathways whilst CFS prevents input into ventral temporal regions but leaves dorsal pathways intact.

stimuli which are non-expressive can in some ways address this limitation. However, note that recent work in which *identical* stimuli were shown to participants in a binocular rivalry paradigm, clearly demonstrated the effect of stimulus meaning (stimuli were paired either with negative, positive or neutral 'gossip') on pre-conscious processing was not related to low-level perceptual processes. Additionally, Said et al. (Said et al., 2011) suggest that trait perception in neutral faces and perception of facial expression rely upon shared mechanisms, suggesting that the facial affect perception differences seen in anxious individuals should also generalise to trait perception in non-expressive faces.

In one anxiety disorder in particular, posttraumatic stress disorder (PTSD), levels of interpersonal trust are especially eroded (Ali et al., 2002). Alienation and disconnection from society in trauma victims with complex forms of PTSD are reported in the clinical literature (Brewin, 2003; Ebert & Dyck, 2004; Herman, 1992) and PTSD is associated with problems with intimacy as well as sociability (Roberts, 1982). Indeed, Cias et al. (2000) not only found that individuals with PTSD reported less trust in other people but, furthermore, suggested that pervasive interpersonal distrust, even in the face of existing family and friend relationships, was a distinguishing characteristic of PTSD compared to other mental health disorders. Schok et al. (2011) report that interpersonal distrust mediates the relationship between perceived threat whilst deployed and subsequent PTSD symptoms amongst Dutch war veterans.

Following from the results of experiment 3, which identified a relationship between self-reported propensity to trust and pre-conscious processing of untrustworthy faces, it is hypothesised that PTSD patients will show differences in preconscious perception of untrustworthy faces. More specifically, it is hypothesised that PTSD veterans will show vigilance (*decreased* time-to-emergence) for untrustworthy faces (relative to neutral). Using a CFS paradigm allows for the investigation of avoidance as well as vigilance behaviours since time-to-emergence on high-trait faces can be compared to the neutral to give a measure of vigilance (speeded response) or avoidance (slowed response).

Whilst no specific literature exists regarding PTSD and dominance perception, evidence of heightened vigilance for *threat*-related stimuli in preconscious processing in PTSD patients leads to the hypothesis that ex-servicemen with PTSD will also show vigilance (*decreased* time-to-emergence) for dominant faces (relative to neutral). Conversely, it is hypothesised that ex-servicemen who do not have PTSD will show the same pattern of time-to-emergence as seen in the previous experiments (i.e. *increased* time-to-emergence for trustworthy and untrustworthy as well as for dominant, when compared to neutral, faces).

Finally, it is hypothesised that PTSD veterans and control veterans will differ in self-reported levels of propensity to trust and social anxiety; no difference between groups is hypothesised for frequency of submissive behaviour. Moreover, within groups, correlations between self-reported traits and avoidance/vigilance indices are hypothesised in the following directions: in the PTSD group it is hypothesised that as reported trust levels increase, untrustworthiness avoidance will increase; in the control group (like in experiment 3) a relationship in the opposite direction is hypothesised (as reported levels of trust increase, untrustworthiness avoidance *decreases*). The relationship between reported submissive behaviour and dominance avoidance is hypothesised to be the same in both groups and to follow that seen in experiment 3: participants who report more frequent submissive behaviour will show great dominance avoidance.

4.4.1 Methods

Participants

Twenty-eight ex-servicemen (all males) took part in experiment 4. All participants had 1) served in the British Armed Forces, 2) been deployed to a conflict zone during their service, and 3) reported combat-related experiences which met the A1 criterion for a traumatic event (as defined by the DSM-IV TR, American Psychiatric Association, 2000) as assessed by the Deployment Risk and Resilience Inventory (DRRI: King et al., 2003).

Two groups of participants were recruited; 1) 12 ex-servicemen who had an existing diagnosis of posttraumatic stress disorder relating to events from their military service and who met criteria for PTSD at the time of testing and 2) 16 ex-servicemen who did not meet criteria for posttraumatic stress disorder (assessed by Posttraumatic Diagnostic Scale; Foa, 1995) at the time of testing but did reach all inclusion criteria defined above. The study was approved by UCL research ethics committee (appendix D).

Participants were largely recruited (23 out of 28 participants) from a database of participants who had taken part in a previous study with the same research group (Andrews et al., 2009). The remaining participants responded to advertisements placed through veterans' support groups. Participants were aged 28 to 57 years at the time of participation. Table 4.1 shows experimental group means (and standard deviations) alongside significance levels for group comparisons. The two groups did not differ in age ($t(26) = 1.51$, $p=.14$) or number of years in service ($t(26) = 0.22$, $p=.83$). However, as required by the recruitment criteria, PTSD veterans reported a significantly greater number of PTSD symptoms. Veterans in the PTSD group also reported a significantly greater number of both combat ($t(26) = 2.81$, $p<.01$) and non-combat ($t(26) = 2.41$, $p<.05$) incidents.

Table 4.1: Group means (and standard deviations) and test statistics (df=26).

	PTSD		controls		t
Age **(years)**	**39.5**	**(5.1)**	**42.6**	**(5.6)**	**1.51**
Years in service	**10.0**	**(5.4)**	**10.4**	**(5.6)**	**0.22**
Combat traumas	**7.92**	**(3.50)**	**4.56**	**(2.83)**	**2.81****
Non-combat traumas	**8.75**	**(3.91)**	**4.88**	**(4.41)**	**2.41***
PTSD symptoms **(as reported on PDS)**	**12.67**	**(2.16)**	**3.25**	**(3.09)**	**9.51*****

* significant at p<.05
** significant at p<.01
*** significant at p<.001

Display apparatus and stimuli

Display properties were identical to experiments 1 and 2. Face stimuli were identical to those utilised in experiment 2; manipulations of trustworthiness and dominance were restricted to (-3, 0, +3) standard deviations on each axis, producing a set of 9 faces covering the extremes as well as the middle point of each axis.

Procedure

Trials were identical to those in experiment 1 and the upright trials in experiment 2. The experiment consisted of 10 blocks of 18 trials. The participant's task was to decide whether the face was on the left or right side of the fixation point by pressing the same keyboard buttons as in the previous experiments.

Materials

As in experiment 3, the Submissive Behaviour Scale (SBS; Allan & Gilbert, 1997), the Propensity to Trust Survey (PTS; Evans & Revelle, 2008) and the brief version of the Fear of Negative Evaluation scale (bFNE; Leary, 1983) were administered to all participants (scales described above) in addition to the following scales.

1. *Posttraumatic stress Diagnostic Scale (PDS; Foa, 1995)*

A 49 item scale which screens for the presence of symptoms of posttraumatic stress disorder. Test items mirror the DSM criteria for PTSD (DSM-IV-TR; American Psychiatric Association, 2000). The PDS has been reported to have high validity, internal consistency, and good test-retest reliability (McCarthy, 2008). It has been widely used in research as well as clinically in instances when the use of a structured clinical interview is not practical. Group allocation in the present study was dependent upon whether participants reported a sufficient number of PTSD symptoms at the level of "2-4 times a week / half the time" in each symptom cluster to meet the DSM-IV TR diagnostic criteria (PTSD group) or not (non-PTSD group).

2. *Deployment Risk and Resilience Inventory (DRRI; King et al., 2003)*

The DRRI is a suite of scales which assess 14 key deployment-related risk and resilience factors. A shortened 45 item version was administered, comprising only three factors (perceived threat, combat experiences, and exposure to the aftermath of battle). The perceived threat section assesses fear for one's safety and well-being in the war zone. Participants rated the fifteen items on a 5-point Likert scale (strongly disagree to strongly agree). This factor measures participants' appraisals of situations rather than objective events. The combat experiences (stereotypical warfare experiences) and aftermath of battle (consequences of combat) sections each consist of 15 dichotomous items which catalogue objective events and circumstances. All scales in the DRRI show good internal consistency (Fikretoglu et al., 2006; King et al., 2006, part 2) and reliability (King et al., 2006, part 3; Vogt et al., 2008) as well as test-retest reliability (Fikretoglu et al., 2006) and strong external validity (King et al., 2006, part 4). Participants who had previously taken part in a study with this research did not complete this scale. Only the dichotomous Y/N items were analysed and participants' previous answers (for those participants who took part in another study with the same research group) were assumed to be unchanged.

Data preparation

Five participants were excluded from the analyses. One participant did not attempt the continuous flash suppression paradigm due to time constraints on the day of testing and another found the task impossible and did not complete testing. A further three participants were excluded for failing to follow task instructions (1 participant), showing no effect of the CFS (1 participant), and for having physical difficulties with his response hand (1 participant). Consequently, N=23 (11 PTSD and 12 non-PTSD participants) for these analyses.

A programming error meant that accuracy data were not recorded and so inaccurate trials could not be removed before analysis as planned. However, experiments 1 and 2 demonstrated that participants perform at ceiling on this paradigm and I am therefore confident that the mean reaction time latencies reported are representative of reaction times for accurate trials.

Time from onset of stimulus to button press response was used as a measure of the time the suppressed stimuli took to break through to awareness. Trial-by-trial 'time-to-emergence' (T2Es) were averaged for each level of trust and dominance of the face stimuli. As in experiments 1 and 2 means were then normalised by calculating z-scores for each participant. Group comparisons employed these normalised T2E scores.

4.4.2 Results and discussion

A 3 (Trust level; -3, 0, +3) x3 (Dominance level; -3, 0, +3) x2 (Group; PTSD, controls) mixed ANOVA revealed a main effect of trustworthiness ($F(2,42) = 5.42$, $p<.01$) as well as a trend towards a significant interaction between trustworthiness and dominance ($F(4,84) = 2.36$, $p=.06$). There was no main effect of dominance level ($F(2,42) = 1.77$, $p=.18$), no main effect of group ($F(1,21) = 0.05$, $p=.82$) and no other interactions reached statistical significance. These main effects partially replicate the patterns seen in experiments 1 and 2. As reported previously, variance in the effect of trustworthiness levels showed linear ($F(1,21) = 7.00$, $p<.05$) as well as quadratic ($F(1,21) = 4.08$, $p=.06$) components. The trustworthiness-dominance interaction showed a linear-quadratic component ($F(1,21) = 5.68$, $p<.05$).

As reported in experiments 1 and 2, untrustworthy faces (trust level -3) emerged from CFS significantly more slowly than did neutral faces ($t(22) = 2.33$, $p<.05$). However, unlike in experiments 1 and 2, trustworthy faces did not show greater t2e than neutral faces ($t(22) = 0.78$, $p=.44$). Figure 4.6 shows normalised mean times-to-emergence for faces at each level of trustworthiness (A) and dominance (B).

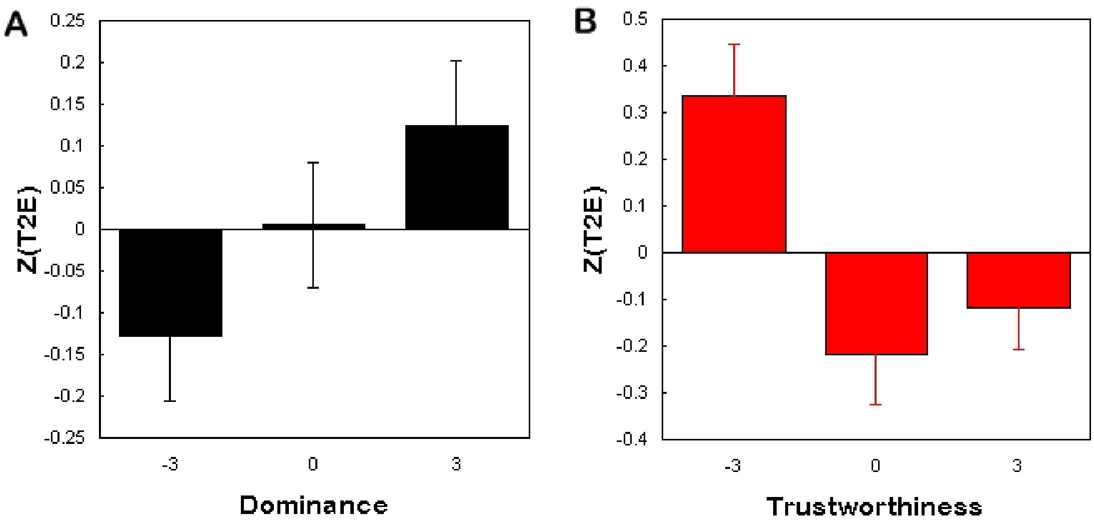


Figure 4.6. Experiment 4 results. Normalized values of time-to-emerge (T2E) averaged across subjects (*N*=23) are plotted against dominance (A) and trustworthiness (B) values of the suppressed faces. Error bars represent the standard error of means.

For untrustworthy and neutrally-trustworthy faces manipulating the dominance level did not have an effect on t2e (F(2,44) = 2.07, p=.11, and F(2,44) = 0.29, p=.75, respectively). However, for trustworthy faces altering the dominance level showed an effect on t2e (F(2,44) = 3.75, p<.05) such that dominant faces were slower to emerge from suppression than both neutral (t(22) = 2.38, p<.05) and submissive faces (t(22) = 2.20, p<.05).

Additionally there was a trend towards an interaction between dominance level and PTSD group (F(2,84) = 2.84, p=.07). Participants with PTSD showed significantly *faster* times for submissive faces (dominance level -3) to break through consciousness than did control participants (t(16.75) = 2.30, p<.05). PTSD and control participants did not differ in times to emergence for either dominant (t(21) = 1.06, p=.30) or neutral faces (t(21) = 0.91, p=.37). Furthermore, PTSD participants showed a main effect of manipulating dominance (F(2,20) = 4.53, P<.05) whilst control participants did not (F(2,22) = 0.09, p=.91; see Figure 4.7)

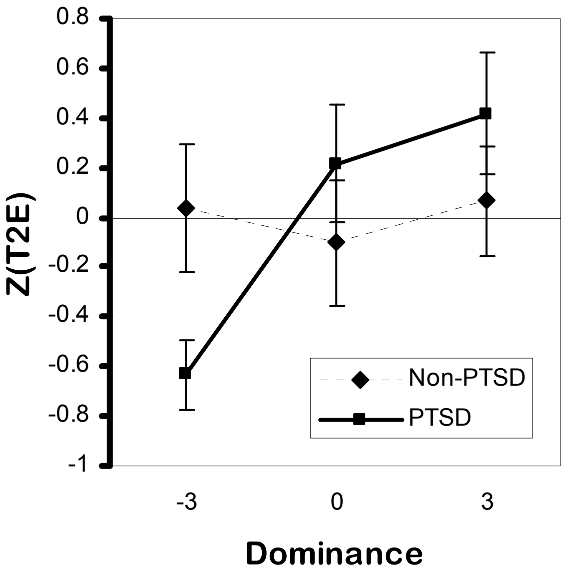


Figure 4.7: Normalized Time-to-emerge (T2E) (*N*=23) plotted against dominance of the suppressed faces (collapsing across trust level). Thick and thin lines correspond to PTSD and non-PTSD groups, respectively. Error bars represent standard error of mean.

These results show partial replication of trust effects reported in previous experiments but no effect of PTSD on preconscious processing of trustworthiness levels of faces. By contrast, dominance effects from previous experiments are not replicated; non-PTSD veterans show no pre-conscious processing of dominance levels whilst PTSD veterans show vigilance or speeding towards submissive faces which has not previously been seen and failed to show any avoidance or slowing for dominant faces as was reported previously.

4.5 General discussion

Experiments 1 and 2 showed that social evaluation of faces along the trust and dominance axes (Oosterhof & Todorov, 2008) extends to preconscious stages of perception. In both experiments, dominant faces that were masked by intraocular suppression took significantly longer to break through suppression compared to same-identity neutral faces. Similarly, along the trust axes, both untrustworthy and trustworthy faces took significantly longer to break through suppression compared to neutral faces. Experiment 2 demonstrated that responses to *consciously* perceived faces do not show a similar modulation by face-trait characteristics ruling out the possibility that a generalized slowing of motor responses to faces *after* conscious perception explain the results of experiment 1.

Experiment 3 showed that the preconscious perception of trust and dominance could be meaningfully related to the observers' relevant personality traits. Participants who rated themselves more likely to trust others showed less preconscious aversion from the untrustworthy (or the dominant) compared to the neutral faces. Those who reported stronger tendencies for submissive social behaviour showed a stronger preconscious aversion to the dominant compared to the neutral faces. The meaningful direction of the correlations between valence-dependent prolongations of suppression and the participants' self-reported personality traits also ruled out the possibility of a generalized slowing of preconscious processing due to some unknown common physical difference between neutral and dominant/untrustworthy faces. Personality traits were not predictive of the variability in the prolonged suppression of the trustworthy (versus neutral) faces (see below for a discussion). The results of these three experiments clearly demonstrate the existence of preconscious social evaluation of faces that depends on both stimulus features and observers' personality characteristics.

Finally, experiment 4 showed that British war veterans largely replicate the pattern of results seen amongst an opportunity sample of students and academic staff. In common with experiments 1 and 2 slowed times-to-emergence for untrustworthy faces were observed (relative to neutral) as well as for dominant faces (relative to submissive). However, unlike previous experiments, slowing was not seen for trustworthy faces.

Moreover, this experiment demonstrated that veterans with posttraumatic stress disorder (PTSD) showed *slower* break-through to consciousness for trustworthy faces (compared to non-PTSD veterans).

Overall, the results were in the opposite direction to the predictions of the evolutionary vigilance hypothesis (Morris et al., 1999; Morris et al., 2001; Vuilleumier, 2005). This hypothesis argues that preconscious face processing is mainly concerned with increasing the chances of survival by contributing to rapid coarse detection of threats i.e. more dominant and less trustworthy faces should have reached awareness first (the opposite of what was found in the present series of experiments). Moreover, the vigilance hypothesis predicts that submissive and/or untrusting individuals should be more sensitive to dominant and/or untrustworthy faces presumably because these types of faces should be motivationally more salient or relevant to them. The individual difference analysis also contradicted this prediction by showing that the more submissive/untrusting participants took *longer* to become aware of the dominant and untrustworthy (when compared to neutral) faces[40].

A possible reason for this discrepancy may be found by considering the different implications of different categories of negative stimuli. A fearful face can be thought of as an indicator of nearby threat but is not itself a direct threat. Upon detecting a fearful face, perhaps a reasonable strategy would be to try and spot the actual source of the threat. Indeed, a number of studies have shown that fearful cues enhance visual contrast sensitivity (Phelps et al., 2006) and visual search efficiency (Krusemark & Li, 2011). On the other hand, an angry face is much less ambiguous in directly showing the source of threat. Indeed, direction of gaze of fearful and angry faces modulates the response time (Adams, Jr. & Kleck, 2003) and amygdala response (Adams, Jr. et al., 2003) to these negative stimuli: faster reaction times and greater amygdala response are observed in response to “angry faces with direct gaze” and “fearful faces with averted gaze”. Importantly, reaction times and brain response to directly gazing fearful faces – which break through CFS faster than neutral faces (Yang et al., 2007) – are significantly different from both direct-gazing angry and gaze-averted fearful faces (Adams, Jr. &

[40] Ex-servicemen showed a different and more complex relationship between personality traits and avoidance indices; furthermore, ex-servicemen with and without PTSD showed distinct relationships.

Kleck, 2003; Adams, Jr. & Kleck, 2003). Consequently, it is possible that the dominant and untrustworthy faces used here are best considered to be direct sources of threat similar to direct-gazing angry faces[41].

Behavioural fear responses to direct threat consist of two opposite extremes. At one extreme, direct threat may induce an active fear response characterized by fight/flight that is mediated by the amygdala, the cholinergic basal forebrain and its neuromodulatory effect on cortical arousal. At the other extreme, encounter with direct threat may induce a passive response characterized by *freezing,* mediated by the amygdala, the brainstem and basal forebrain system (Pape, 2010). Freezing behaviour has been extensively studied in rodents and nonhuman primates. But much less research has been done on freezing in humans. The prolonged preconscious perception of dominant and untrustworthy faces reported in the present studies may in fact be the result of a passive fear response leading to slowed visual perception. In this view, a passive fear response (or a kind of 'cognitive freezing') is initiated by the amygdala and is possibly mediated via reduction of neuromodulatory influence of the basal forebrain system on cerebral cortex leading to reduced cortical arousal and prolonged suppression of threat-related stimuli (Pape, 2010). The individual difference findings of experiment 3 are also consistent with this notion: cognitive freezing (i.e. a preconscious fear response) was stronger in the more submissive, untrusting personality types who were presumably more likely to take the threat more seriously.

This view yields several testable predictions: the human amygdala and the visual cortex response to suppressed faces should distinguish between preconscious dominant/untrustworthy and neutral faces *in opposite directions*: preconscious dominant/untrustworthy faces should elicit stronger responses in amygdala and weaker responses in the visual cortex. These opposite effects should correlate with observer personality traits. Furthermore, patients with bilateral amygdala lesions should not show the prolonged suppression for dominant/untrustworthy faces (Adolphs et al., 1994). If these predictions are borne out by future research, then the paradigm employed here could become an ideal non-invasive laboratory model for studying human passive fear responses.

[41] This notion generates a number of readily testable predictions for future studies. For example, fearful faces with averted gaze should take longer to break through suppression than those with direct gaze.

An alternative account of the findings could be suppression or avoidance[42] of stimuli at a preconscious level. Whilst freezing results in a down-regulation of cortical responsiveness, pre-conscious suppression or avoidance requires an *increase* in top-down cortical involvement. Neurocognitive models of anxiety response posit a top-down regulatory role for pre-frontal cortex (Bishop, 2007) such that the amygdala response is down-regulated by pre-frontal inputs. As such, this view makes the testable prediction that the human amygdala and the pre-frontal cortex response to suppressed dominant/untrustworthy faces should be *in the same direction* but with a temporal lag: preconscious dominant/untrustworthy faces (compared to neutral) should elicit stronger responses in amygdala and this should result in stronger PFC response in order to achieve down-regulation (amongst individuals who are capable of such down-regulation).

This prediction has the interesting extension that anxious individuals should show clearly differentiable neural responses to suppressed dominant/untrustworthy faces. High trait anxiety has been associated with both hyper-responsivity of amygdala and hypo-responsivity of pre-frontal cortex (Bishop, 2009). Consequently, if pre-frontal regulation does play a role in the results seen in the CFS paradigm, it is expected that highly anxious individuals would show extended preconscious processing of dominant/untrustworthy faces. This behavioural prediction was partly tested[43] by experiment 4 which provided some evidence for altered pre-conscious processing of faces in a group of anxiety disorder (PTSD) patients.

Experiment 2 showed that the effects seen pre-consciously were not replicated when stimuli were presented without continuous flash suppression. However, the reaction times in this conscious condition showed a flat pattern in contrast to the pattern of results seen in the non-conscious condition. It is possible that this conscious condition captures only participants' fastest response time and consequently is hindered by a floor effect. Future work should try to find an alternative method of conscious presentation

[42] This is not attentional avoidance as discussed in previous chapters; in the CFS paradigm utilised in the present study, attention can be confidently assumed to be deployed in the location of the face stimuli at all times since this is necessary for the flash suppression to be effective. As a consequence, this paradigm does not allow for *attentional* avoidance.
[43] PTSD is unique amongst anxiety disorders and may not represent a robust testing of this prediction. Future studies could investigate other anxiety disorder populations or non-clinical elevated trait anxiety.

which does not result in such quick reaction times in order to allow for any variation in behaviour to be captured by the reaction times. Only then could the alternative explanation that the non-conscious pattern of results represent a response bias or other conscious process, be rejected.

In all CFS experiments, a U-shaped pattern of response was observed for the preconscious perception of trust: both trustworthy and untrustworthy faces took longer to emerge into awareness compared to neutral faces[44]. These behavioural findings parallel a number of recent works that have reported a similar quadratic pattern of human brain – most predominantly human amygdala – response to face trustworthiness (Said et al., 2009; Todorov et al., 2008a; Todorov et al., 2011). It has recently been argued (Said et al., 2010) that neuronal responses in the human amygdala and fusiform face area may be driven by the *distance* from the average face. Face typicality has been shown to co-vary with trust but not dominance (Todorov et al., 2011). Therefore, an alternative interpretation of the U-shape pattern of findings reported here could be that the typical (average face) emerges faster than the atypical trustworthy and untrustworthy faces. However, this interpretation alone cannot account for why individual differences are predictive of variation in T2E for untrustworthy but not trustworthy faces. Together, these opposite considerations suggest that preconscious processing of trustworthy and untrustworthy faces may be driven by different underlying mechanisms. For future research, it would be interesting to compare CFS responses to faces that are matched on distance to the average face but mismatched on social valence, for example by using stimuli similar to Said and colleagues (2010).

The results from experiment 4 reveal a lack of suppression/freezing/avoidance for dominant faces in war veterans and, moreover, an opposite pattern of activation/fighting/approach/vigilance in veterans with PTSD for submissive faces. One possible explanation for the observed vigilance for submissive faces reflects the more feminine look of these faces and the entirely male sample of war veterans in experiment 4 (earlier experiments included females in their participant group). However, gender differences between groups of participants do not account for the fact that PTSD and non-PTSD veterans differ in their vigilance for submissive faces since both groups were

[44] In experiments 1 and 2 this result was statistically significant; this result was only partially supported in experiment 4 although the same pattern of time-to-emergence was evident.

entirely male. Possibly PTSD does indeed alter vigilance for salient stimuli but 'salient' for PTSD patients is not necessarily threat-related (i.e. untrustworthy/dominant faces in the present study). PTSD patients report hypervigilance but the focus of this vigilance has previously been presumed to be either generally threat-related or specifically trauma-related. Future work could investigate links between threat-biases (as reported in the cognitive psychology literature on attention biases and PTSD) and reported vigilance behaviours.

Small differences between the results of experiment 4 and those of experiments 1 and 2 may reflect the fact that war veterans are distinct from the other participant groups in a number of ways. First, as stated above, all participants in experiment 4 were male. Tan et al (2011) report gender differences amongst high trait anxious participants in pre-conscious processing of stimuli[45]. Second, all veterans reported combat exposure as a necessary inclusion criterion and all veterans had received British military training which commonly includes vigilance exercises. It is possible that either of these facts means that differences between veterans and non-veterans would be expected in pre-conscious processing of threat-related stimuli.

In summary, the present set of experiments speaks against the claim that apparent prioritisation of threat stimuli (as shown, for example, in Adams et al., 2010) might reflect low-level salience of threatening face stimuli (Yang et al., 2007; Gray et al., 2010); variation in pre-conscious face processing has been shown to be explained by observer as well as stimulus differences. This finding is in line with recent work showing that neutral faces paired with negative gossip dominate in a binocular rivalry task (Anderson et al., 2011) suggesting that pre-conscious processing of visual stimuli can be influenced by non-visual features.

The present set of experiments discloses and emphasizes the importance of individual differences in personality traits and their relevance to face perception. Highlighting the relevance of variability in observer-specific traits for face perception may provide clues for explaining some of the discrepancies in unconscious high level face perception

[45] Tan and colleagues report avoidance in males, however, it should be noted that theirs was a paradigm designed to assess attentional engagement and disengagement with preconscious stimuli and, consequently, is not directly comparable with the present set of experiments.

literature. The seemingly contradictory results from previous work that investigated high level face adaptation (Adams et al., 2010; Amihai et al., 2010; Moradi et al., 2005) may be explained by individual differences between their participants arising from personality traits as well as structural brain differences (Kanai & Rees, 2011). The relatively small sample sizes employed in psychophysical studies of adaptation may have exacerbated this situation. This issue is of special relevance because traditionally, the holy grail of psychophysical research has been to identify the principles governing perception that are independent of observers. This goal is often pursued by focusing on extensive data collection from small numbers of participants making the assumption that between-observer differences must be of little relevance. The present results, along with some other recent findings (Gray et al., 2009), caution against such simplifying assumptions.

Chapter 5: Hypervigilance without Threat: Eye-Movements Reveal Vigilant Behaviours

Attentional bias for threat is commonly divided into engagement and disengagement processes with evidence for altered processing in anxious individuals at both stages (Bar-Haim et al., 2007). Heightened orientation and engagement with threat items is frequently referred to as *vigilance* for threat and, temptingly, the symptom of *hyper*vigilance even forms a part of the diagnostic criteria for two of the seven anxiety disorders (PTSD and Acute Stress Disorder (PTSD and Acute Stress Disorder; American Psychiatric Association, 2000) and previously formed part of the diagnostic criteria for additional anxiety disorders (American Psychiatric Association, 1980). It has been suggested that these crucial threat biases are underpinned by anxious individuals' willingness to adopt a vigilant mode of processing (Mathews & MacLeod, 2002). However, 'vigilance' is ill-defined and clinical and cognitive psychology usage contains a number of inconsistencies which undermine the assumed links between elevated attentional bias for threat and the symptom hypervigilance.

Hypervigilance to threat is one of the core symptoms of posttraumatic stress disorder (PTSD). This excessive watchfulness or checking one's surroundings over and above what is considered normal is commonly reported by patients as being highly impairing. It has been suggested to be not only key in maintaining the disorder but possibly even causative in onset (Constans, 2005). Mathews (1990) suggests that anxiety and vigilance for threat reinforce each other in a 'vicious cycle' and that this cycle maintains anxiety disorders; being anxious leads to a vigilant threat-seeking mode which, in turn, leads to further anxiety because more threats are identified. Whilst this model provides an intuitively reasonable account of the relationship between threat bias and anxiety, and whilst evidence for causal links between the two is growing (Bar-Haim, 2010; Beard, 2011; Browning et al., 2010; Hakamata et al., 2010), a "vigilant threat-seeking mode" is somewhat different to threat-prioritisation which has been demonstrated in many attention bias paradigms. In paradigms such as the dot probe task and its modifications participants are presented with both threat and non-threat items and it is the speeding or slowing of responses to threat (over neutral) which indicates the presence of attentional bias. However, in both clinical anxiety terms and according to Mathews, threat-*seeking* is anxiety's defining attentional alteration; the presence of actual threat is not required for this behaviour to take place. This chapter reports two experiments which aim to measure vigilant threat-*seeking* in the absence of objective threat stimuli.

Some anxious individuals (including individuals with elevated but non-clinical levels of anxiety) report being aware of preferential threat-processing behaviours. However, awareness of threat bias is not a *necessary* condition for its existence. Threat bias has been shown at pre-conscious stages of processing (Carlson & Reinke, 2008; Mogg et al., 1994; Mogg et al., 1995b) and even clinically anxious individuals may be unaware that they show speeded processing of threat. Non-patients with elevated trait anxiety generally do not report scanning their environment for threat or being excessively watchful or on guard (criteria for the clinical symptom of hypervigilance) despite showing equivalent sized threat biases to anxiety disorder patients (Bar-Haim et al., 2007); awareness of modified attentional bias towards threat is clearly not a necessary condition for its existence. Conversely, hypervigilance as a clinical symptom necessarily requires awareness (for it to be reported by patients). The assumption in the cognitive literature has largely been that non-conscious attention biases are eventually identified by patients as problematic after they have persisted for some time. However, this sits uncomfortably with research which suggests that hypervigilance is the *first* symptom to be identified by patients who later develop delayed-onset PTSD (Andrews et al., 2009) and also with the lack of evidence to date for any identifiable relationship between conscious and non-conscious threat biases.

In the previous chapter self-reported personality traits were shown to be related to pre-conscious face-processing. This relationship partially extended to clinically relevant phenomena in a sample of PTSD patients. In the present chapter, I aim to investigate whether the clinically-reported (consciously-accessible) symptom of hypervigilance is measurable via an automatic non-conscious behaviour; eye-movements.

Tracking eye movements has frequently been used as a proxy for identifying attentional focus. In order to process a visual stimulus in detail we must direct the fovea of the eye towards it and, consequently, recording where the eyes are directed allows us to deduce likely foci of attention in a more direct way than paradigms such as dot probe and emotional Stroop tasks which are mediated by verbal or manual responses. Locations of overt and covert attention do not share a one-to-one mapping but they are generally coupled (Deubel & Schneider, 1996). Evidence that common neural activity underpins attention and oculomotor processes further validates the use of eye-tracking paradigms to assess attention (e.g. Corbetta et al., 1998; Nobre et al., 2000).

Commonly, movements of the eyes are measured by identifying the centre of one pupil[46] and recording its position throughout a task. Eye-movements can be divided into three broad categories which depend on partially different brain structures: fixations, saccades, and smooth movements. Our eyes are never completely still so 'fixations' must be regarded as a relative term; fixational eye movements are tiny shifts which still maintain the direction of gaze. Saccades are the movements which link between these fixations. Saccadic eye-movements are the fastest movements produced by the human body and once initiated they cannot be altered consciously. The final type of eye-movement, smooth movements, occur either when the eyes follow a moving object, or when gaze position remains fixed but the head moves causing the eyes to swivel. The first of these is known as smooth pursuit and, unlike with saccadic eye movements, targets for these smooth movements are only loosely coupled with attentional focus (Souto & Kerzel, 2008). The second of these smooth movements is a reflex eye-movement known as vestibulo-ocular reflex which is largely controlled by the vestibular (balance) system and not dependent on visual input.

Consequently, saccades and fixations are the eye-movements of most relevance in investigations of attention and, since saccades generally begin and end with fixations, these two types of eye-movements are closely linked. Work on vigilance to threat has generally reported location of fixations (threat vs non-threat), speed of initiation of first saccade (to threat), and duration of fixations (also sometimes referred to as dwell time and linked to the concepts of delayed disengagement and avoidance from the attentional bias literature). However, in the present study, different eye-movement variables were selected as being of primary interest because: 1) the paradigms were free-viewing ones

[46] The eyes are assumed to move in tandem.

with naturalistic stimuli in which participants were not required to 'choose' between threat and non-threat locations (fixation to threat versus non-threat was therefore not meaningful, nor dwell time on threat versus non-threat items), nor were participants required to respond to stimuli which had pre-determined onsets (consequently, accuracy and response latencies could not be derived); and 2) variables were chosen to reflect the hypervigilant behaviours reported by patients. As a result, variables which reflected the hyper-scanning mode of processing, as described below, were selected for analysis.

Eye-tracking studies of attentional processes in anxiety have largely confirmed the vigilant-avoidant pattern of responding which is hypothesised and reported in the behavioural literature; anxious individuals look more quickly towards, but subsequently resist looking at, threatening stimuli (Pflugshaupt et al., 2005; Rinck & Becker, 2006; Wieser et al., 2009a)[47]. This vigilance-avoidance pattern of attention to threat replicates that which is posited from assessments of attention biases based upon manual responses (Derakshan et al., 2007; Mogg & Bradley, 1998).

However, a vigilance-avoidance pattern of attentional processing does not appear to capture patient reports of the symptom of hypervigilance in which a vigilant scanning mode is adopted irrespective of threat presence. Patients describe extensive visual search of an environment that they feel is threatening including "checking" potentially threatening locations (that are perhaps otherwise not relevant to the task at hand). Some eye-tracking evidence for this hypervigilant mode of processing has been reported in anxious individuals; Horley and colleagues (2003; 2004) found evidence for what they termed "hyperscanning" of photographs of faces in social phobics. Hyperscanning was indexed by increased scan-path length (total distance between all eye-movements) as well as alterations in both number and duration of fixations[48]; in the earlier of the two studies social phobics showed a reduction in number and duration of fixations (Horley et al., 2003). Conversely, in their follow-up study control subjects showed a reduction in fixations (number and total fixation duration) whilst social phobics did not (Horley et al., 2004). Moreover, Horley et al., (2004) found that the degree of oculomotor gaze

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[47] But Pflugshaupt et al. (2007) report slowed scanning along with avoidance of spider stimuli and hyperfixation of the eye region in social phobics has also been reported (Wieser et al., 2009b).

[48] Horley et al. (2003) also report that schizophrenics, by contrast, show "restricted" scanpaths when viewing face stimuli and that these are indicated by fewer fixations, longer fixation durations and reduced scanpath length.

avoidance (measured by assessing number and duration of fixations to the eye-regions of faces) was related to social phobia symptom severity, indicating that eye-movement patterns may in fact capture behaviours which are highly relevant to the disorder. Additionally, there was some evidence that social phobics (compared to a control group) engaged in hyperscanning even with neutral, non-expressive faces (Horley et al., 2003).

Work with spider phobics has shown that they make fewer but longer fixations to animal photographs in general and, like in Horley et al. (2003), fewer and *shorter* fixations to threat (spider) stimuli (Pflugshaupt et al., 2007). However, this study did not find any scan-path differences between phobics and control subjects. One final study has attempted to capture hyperscanning; Freeman et al. (2000) found no evidence of excessive scanning in GAD patients (measured by number of areas gazed upon and percentage of gaze time in informative areas) for either neutral or threatening scenes[49]. This null finding directly contrasts with other studies investigating hyperscanning. The authors suggest that the null findings are difficult to draw strong conclusions from and may reflect the laboratory setting and the fact that stimuli were not relevant to the content of participants' anxiety concerns. Additionally, it should be remembered that, in contrast to PTSD, hypervigilance does not form a part of the diagnostic criteria for either phobia or GAD. It therefore remains an open question whether the excessive scanning of hypervigilance that is reported clinically can be captured by an eye-tracking paradigm.

A large proportion of the eye-tracking work investigating anxiety has focussed upon social phobics' processing of face stimuli. Phobias in general have received a disproportionate amount of attention in this literature because the specificity of their anxiety focus facilitates selection of relevant visual stimuli; it is as yet unclear to what extent findings from the phobics generalise to all anxiety disorders (or to models of elevated levels of non-clinical anxiety). A recent review of scanpath analyses in psychopathology concluded that anxiety research has failed to yield coherent results (Toh et al., 2011 in press). In social phobics, avoidance of eye-contact (following speeded attention to the eye-region) has been hypothesised to be a submissive gesture

[49] This study did not report scan-path analyses, however.

intended to lessen the effect of potential danger (Horley et al., 2003; Horley et al., 2004) and as such may reflect strategic coping behaviour rather than altered information processing. Pflugshaupt et al. (2007) found that the self-reported severity of social avoidance symptoms was not related to fixation or scan-path differences in their group of social phobics. As a result, it is unclear whether vigilance and avoidance are in any way related to hyperscanning and the symptom of hypervigilance.

Eye-tracking work amongst PTSD patients has provided evidence of an increased number of initial fixations to trauma-relevant words (Bryant et al., 1995) and images (Kimble et al., 2010) compared to controls and, additionally, increased arousal (indexed by an increased number of skin-conductance responses) during these fixations (Felmingham et al., 2011). No evidence of subsequent avoidance of threat items has been found and Kimble et al. (2010) report instead *more* time spent looking at trauma-related items for war veterans high in PTSD symptoms compared to those with only a few or no PTSD symptoms. Work by Beevers and colleagues (2011) suggests that *avoidance* of fearful faces (shorter fixation durations towards these stimuli) prior to trauma exposure predicts later PTSD symptomatology[50]. However, no work to date has attempted to investigate hyperscanning in PTSD patients and it is unclear whether evidence of vigilance and increased dwell time in patients has any likely correlate in scanning behaviours.

In addition to the work on attentional biases and hyperscanning, eye-tracking studies have begun to contribute to the wider clinical psychology literature. A wealth of work has looked at smooth pursuit differences in schizophrenic individuals and these altered eye-movements are now considered a potential biomarker of schizophrenia (Beedie et al., 2011). Additionally, schizophrenics also show saccadic alterations (Mahlberg et al., 2001). Other psychiatric populations have also shown distinctive patterns of eye-movements (e.g. autistics: Fletcher-Watson et al., 2009) and there is increasing interest in linking these patterns to information processing and later cognition. Amongst PTSD patients, work has shown that PTSD with secondary psychotic symptoms is associated with a pattern of smooth pursuit which is distinct from both psychosis patients and

[50] This work is analogous to recent work using the dot probe task which has shown that avoidance of threat during trauma exposure predicts number of PTSD symptoms at 6 and 12 month follow-up (Wald et al., 2011a; 2011b).

controls (Cerbone et al., 2003). No evidence has been reported for patients with PTSD *without* psychotic symptoms showing differences in smooth pursuit movements and, as noted previously, the present study does not attempt to assess smooth movements due to their lack of association with attention processes.

The present study attempts to measure the symptom of hypervigilance (as reported by patients) using two eye-tracking methods during behavioural tasks with non-threatening stimuli. Two groups of participants were recruited; previously deployed ex-servicemen who had experienced an A1 trauma but never developed PTSD and a group of PTSD-diagnosed ex-servicemen. The two tasks attempt to replicate the conditions under which hypervigilance is commonly reported as occurring in this population; in a laboratory-based task, participants were asked to freely view street scenes whilst their eye-movements are measured; in a more naturalistic task, participants wore a portable eye-tracking device whilst walking along unknown London streets. These stimuli and settings correspond to patients' reports about situations in which hypervigilance behaviours are prevalent and, as such, this study aims to use cognitive psychology methods to capture clinically-reported behaviours. This methodological approach differs from previous work on hypervigilance because it attempts to capture a measurable behavioural correlate of a clinically reported symptom rather than investigating processes (attention bias to threat) believed to lead to hypervigilant behaviour.

Previous work suggests fewer but longer fixations should be expected in the PTSD group with no differences in scan-path lengths between groups (Horley et al., 2003; Pflugshaupt et al., 2007). However, these findings directly contradict patient reports and were based upon a different patient group than that investigated in the present study. Instead it was hypothesised that eye-movement differences would be in line with participants' reports of their subjective experience of hypervigilance. That is to say that, PTSD patients (relative to trauma-exposed controls) should show more frequent saccades and fixations, with fixations of shorter durations. Moreover, a pattern of 'hyperscanning' would be expected in PTSD patients, evidenced by increased scan-path length.

Participants were interviewed about their experiences of hypervigilance in order to 1) establish if the paradigms chosen truly do reflect locations where participants' hypervigilance behaviours are prevalent, 2) quantify the severity of hypervigilance for each participant. It was hypothesised that in addition to PTSD group differences, a relationship would exist between eye-movement parameters and self-reported severity of hypervigilance. This is expected to be true in both laboratory and naturalistic settings but perhaps particularly so in the naturalistic task (if indeed this setting equates to the situation in which patients report experiencing frequent hypervigilant behaviours).

5.1 Method

5.1.1 Participants

Twenty-eight ex-servicemen participated in the study; these were the same participants as reported in experiment 4 of the previous chapter. Two groups of ex-servicemen were recruited; 1) 12 veterans who had an existing diagnosis of posttraumatic stress disorder relating to events from their military service and who met criteria for PTSD at the time of testing (assessed by Posttraumatic Diagnostic Scale; Foa, 1995) and 2) 16 veterans who did not meet criteria for posttraumatic stress disorder at the time of testing. As reported previously, all participants had 1) served in the British Armed Forces, 2) been deployed to a conflict zone during their service, and 3) reported combat-related experiences which met the A1 criterion for a traumatic event (as defined by the DSM-IV TR, American Psychiatric Association, 2000). The study was approved by UCL research ethics committee (appendix D).

The two experimental groups did not differ in age or years in service. However, as required by the experimental design, PTSD veterans reported a significantly greater number of PTSD symptoms than non-PTSD veterans. Additionally, PTSD veterans reported a significantly greater number of both combat and non-combat incidents and more severe levels of hypervigilance (assessed by the Clinician Administered PTSD Scale; Weathers et al., 2001). Table 5.1 shows group means (and standard deviations) alongside significance levels for each of these measures.

5.1.2 Procedure

Participants attended a day of testing during which seven experimental tasks as well as questionnaires and a brief interview were completed. Data are presented in this chapter from the two eye-tracking paradigms which were performed. Participants always completed the tasks in the following order (although other tasks were interleaved in a fixed order): 1) PDS and DRRI questionnaires, 2) scene-viewing task, 3) street-walk head-mounted eye-tracking task, 4) trait and state questionnaires and hypervigilance symptom interview. This order was maintained for two major reasons which pertain to the eye-tracking tasks: 1) hypervigilance symptom interview did not occur until *after* the two tasks were complete in order to ensure participants were naïve to the hypotheses; 2) the street-walk task always took place *after* the scene-view task ensuring that stimuli viewed during the scene-view task were novel to participants.

5.1.3 Scene-viewing task

Participants were asked to freely view 40 photographs of British streets in four blocks of 10 photographs. Scenes were presented full-screen on a 19 inch Hitachi CM769ET monitor for 7 seconds each. Whilst stimuli were presented, participants were instructed to imagine themselves standing on each street. After each block participants were briefly shown each image once again and asked to make threat ratings (0 = no threat to 100 = extreme threat).

Trials were separated by an inter-stimulus interval of at least 1000 ms (each trial began with a correction of any eye drift). Participants sat 57cm from the screen with their head in a fixed position supported by a chin rest whilst eye position information from the right eye was recorded by an SMI Eyelink I system with a sampling rate of 250 Hz. The experimental task was programmed in E-prime 2.0. Block and scene-order-within-block were both randomised. Each block was preceded by a nine-point pupil-locator calibration of the Eyelink system.

Materials

Forty street-scene photographs of urban and suburban streets were captured from Google Streetview (http://maps.google.co.uk) and cropped to 1024 by 768 pixels. Ten of the images were busy streets containing people and six were photographs of the London streets which formed part of the route for the portable eye-tracking task. Sample stimuli are shown in appendix E.

Data Extraction

Saccades, fixations and blinks were automatically identified by the Eyelink I system. Saccades were defined according to manufacturer settings for amplitude and acceleration criteria (minimum displacement = 10 degrees; minimum speed = 30 degrees/sec; minimum acceleration = 8000 degrees/sec^2); fixations were defined as all movements not reaching criteria for saccades; blinks were identified when the pupil was not located by the eye-tracker. Scan-path length was calculated in pixels (and converted to degrees; 28 pixels per degree of visual angle) as the sum of differences between pupil locations for all data-points recorded. Mean values across trials were calculated for each dependent variable for each participant.

5.1.4 Portable eye-tracking of naturalistic behaviour

Participants walked a set 230m route (Figure 5.1) at a London location near to the Institute of Cognitive Neuroscience whilst wearing a portable, head-mounted eye-tracking device, supplied by Positive Science (www.positivescience.com). The device consisted of a small, lightweight JVC GR-DF470 video-camera mounted in a light-weight backpack which recorded input from two cameras mounted on a pair of spectacle frames worn by the participant. The video-camera's field of view was split optically so that it recorded the participant's view ahead in one half of the screen and the (right) eye in the other half. Thus the observer's viewpoint and the eye (with its movements) were recorded together onto the video-camera, recording at a rate of 29.973 frames per second; having both images in one frame guaranteed the consistency of time across the two images. Participants were instructed to walk as they would normally and were not informed of any of the hypotheses. The walk lasted approximately 2.5 minutes (approximately 4500 frames per participant).

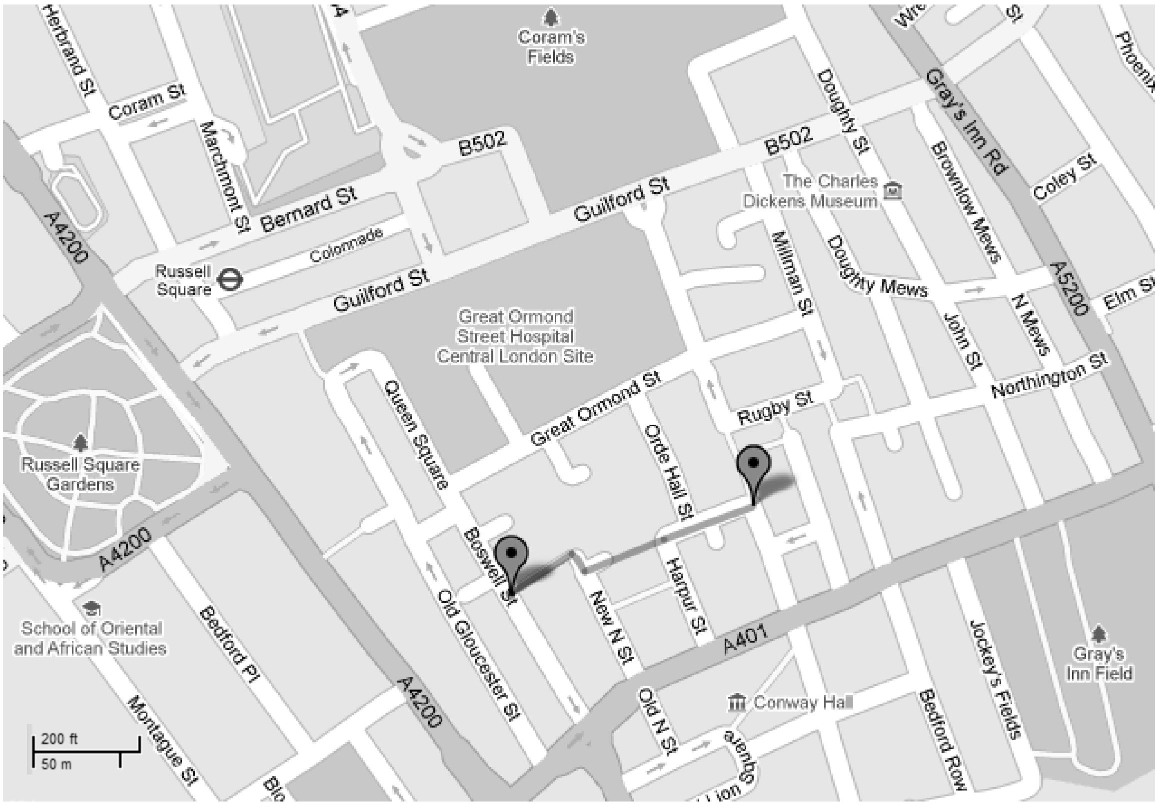

Figure 5.1: Route walked by participants whilst observer viewpoint and eye-movements were recorded (scale is approximate).

Data Extraction

The split-frame video files were analysed frame by frame with the help of a purpose-built program (Sly-Tracker, program details in appendix F) written in Matlab and using the Image Processing toolbox (Matlab R2006a, Mathworks Inc.). Threshold light level was fixed by the program and used to derive possible locations for the pupil (areas of the image which exceeded this threshold). An algorithm was then applied (see appendix F) to select the most likely pupil location. The appropriate threshold value varies between individuals but also between frames for any individual, depending on changing light level in the environment as well as direction of view. There are no algorithms to capture this variation and, consequently, threshold values were verified manually for each frame in order to ensure accurate pupil location.

Saccades (eye-movements at speeds above 30 degrees/sec), smooth motions (eye-movements at speeds between 5 and 30 degrees/sec), fixations (no eye movement or eye-movements at speeds not reaching 5 degrees/sec), and blinks (all other frames) were automatically identified although only saccades and fixations were analysed. Scan-path length (degrees) was calculated as the sum of distances between all fixations. For each participant frequency variables were derived from raw counts of the different eye-movement types by dividing by the total number of frames which the defined route took to walk and multiplying by the recording rate of 29.973 frames per second (thereby compensating for differences in walking speeds of participants).

5.1.5 Clinical Measures

Trait and state questionnaires

The Deployment Risk and Resilience Inventory (DRRI; King et al., 2003; King et al., 2006) and the Post-traumatic Stress Diagnostic Scale (PDS; Foa, 1995) were administered as described in the previous chapter. Scores on these questionnaires dictated inclusion in the study and group assignment respectively.

Interview Protocol

The Clinician Administered PTSD Scale (CAPS; Blake et al., 1995) is a 30-item structured interview that corresponds to the DSM-IV criteria for PTSD (American Psychiatric Association, 2000). It has excellent reliability and validity (Weathers et al., 2001). In the present study only the hypervigilance item was administered (see appendix G). Interviews open with the question "Have you been especially alert or watchful, even when there was no real need to be?**"** Follow-up questions ask how often this behaviour happens, why, when it began, what difficulties it causes, and how much effort is required. Each item in the CAPS is rated for frequency and intensity on a 5-point scale. Transcripts of the interviews were rated by the experimenter and seventeen transcripts were also by a clinical psychologist blind to participants' PTSD status. Hypervigilance severity scores were calculated by summing the frequency and intensity ratings for each symptom. Inter-rater reliability was high for total scores (Pearson's r = 0.79, $p<.001$).

5.2 Results

All analyses were conducted on SPSS v.14. Table 5.1 shows experimental group means for demographic variables, alongside the test statistic for group comparisons.

Table 5.1: Demographic variables for the two experimental groups; group means (and standard deviations) and test statistics (independent measures t-tests, df=26).

	PTSD		controls		t
Age **(years)**	**39.5**	**(5.1)**	**42.6**	**(5.6)**	**1.51**
Years in service	**10.0**	**(5.4)**	**10.4**	**(5.6)**	**0.22**
Combat traumas	**7.92**	**(3.50)**	**4.56**	**(2.83)**	**2.81****
Non-combat traumas	**8.75**	**(3.91)**	**4.88**	**(4.41)**	**2.41***
PTSD symptomatology[51] **(as reported on PDS)**	**12.67**	**(2.16)**	**3.25**	**(3.09)**	**9.51*****
Hypervigilance severity **(CAPS total score)**	**6.17**	**(1.70)**	**3.28**	**(2.95)**	**3.26****

* significant at p<.05; ** significant at p<.01; *** significant at p<.001

5.2.1 Patient Reports of Hypervigilance

The CAPS hypervigilance interviews were scored as described previously and a severity total score was calculated for each participant. Inspection of table 5.1 above shows that non-PTSD participants did not all report a complete absence of hypervigilance. In fact, 7 of 16 non-PTSD participants met criteria[52] for clinical levels of hypervigilance (11 out of 12 PTSD participants also did). This unexpected observation made our hypotheses about relationships between hypervigilance severity and eye-tracking variables applicable *across* experimental groups, rather than restricted solely to the PTSD group. Responses from participants to interview questions confirmed a number of features of hypervigilance in our military sample which are relevant to our interpretation and discussion of eye-tracking results. Quotes given in this section illustrate these key features.

[51] PTSD symptomatology reported here is the sum of severity scores for each item on the PDS; later analyses of PTSD symptomatology which also include hypervigilance severity utilise a PDS symptom total which excludes the hypervigilance item of the questionnaire. This is done to ensure PTSD symptomatology scores are not driven by hypervigilance severity scores.

[52] The most commonly used scoring rule is to count a symptom as present if it has a frequency of 1 or more and an intensity of 2 or more.

As expected, a large number of participants reported hypervigilance which was specifically related to walking along unknown streets.

> *"...Looking all over the place; people leaning out of windows, weird dark shadows, coming out of windows..."* participant 0046
>
> *"...its one of those things that you become attuned to, you're trying to make sure that you're scanning the whole of the area as you're walking around... You know, just forever watching. Er... looking at the height just to make sure there's no positions where people could be looking down on you and so on..."*
>
> participant 0081
>
> *"Yeah... to me it's the most common-sense thing to do. I would never walk down a road hugging the dark side of a building, with various doorways hidden back in, and not expect to get jumped. I'd be asking to get jumped... if the wall isn't true all the way along, you know, as in, just a wall, walk in the middle of the road. That way you've got, you can gonna be seen or they've got to come to you to get you... if you can see what's coming at you."*
>
> participant 0129
>
> *"I just feel I'm hypervigilant all the time, especially if I go to somewhere I don't know, like walking through here. I'll look at windows, look at cars, look at -, it just seems a natural instinct to do."*
>
> participant 0134
>
> *"... it's like a threat assessment, a constant threat assessment. You're looking for ways out, erm... not necessarily take cover or anything but you're looking for threats from above but also you're looking for routes out, they're also routes in so you're looking at them as well. Err... just basically if anything went wrong I know I could go there, or if I'm walking on that side of the road I know that I can go behind that, I can dart into that doorway, I can go down that alley, down that side road, equally I know that that's where threat can come from so that's, that's what I'm sort-a looking at."*
>
> participant 0271
>
> *"... like, if I walk down the street I always start looking for possible, like... my mind just won't switch off from army stuff, it's all like, right, someone might be hiding behind that car, there might be someone in that car, behind that fence, in that, I'm just constantly keeping my eye open for danger."*
>
> participant 0336

Moreover, this vigilance was unconnected to the presence of actual threat, and persisted even in the absence of any threat and the awareness that the situation was non-threatening.

> *"…But every time it happens I still feel I'm under attack, even though something might not be happening. And I'll try and convince myself that everything's alright, nothings happening out there but it still don't take away that feeling of being attacked."* participant 0045
>
> *"I know really that nothing's gonna happen to me but it's just, it's more a protection I think. Like today on the train or on the tube, I knew nothing was gonna happen but I was just thinking what if… what would I do if, where would I go?"* participant 0134
>
> *"I sometimes obviously feel it's totally excessive. Um… I used to go and buy twenty fags and I'd come out of the – and I'd notice myself doing it and I dunno why. I'd open the door, quick left, right, scoot, go. And almost trying to get out as quick as you can. Have a quick scoot and you're out. And I think why would I do that? It's a f**king, it's an off licence, who's going to try and do me in an off licence? What a stupid thing to think! I don't mean to do it."*
> participant 6007
>
> *"I know there's nothing that can hurt me, there's no danger towards me but I'm always constantly looking out for danger."*
> participant 6010

Hypervigilance was commonly reported as an automatic and uncontrollable behaviour despite being available to conscious awareness.

> *"It's like breathing. You do it… [heavy exhalation]… to not do that would be harder than, yeah, to not do it right now would be harder not to do it than to do it."* participant 0129
>
> *"I could put no effort into behaving like that. The effort's in trying to behave not like that."* participant 0517
>
> *"… it's hard to say how much effort you put into it because, er, it's just something you do, every day and it's, it sounds silly doesn't it? It sounds really really silly."* participant 6007

"I don't try, it's just a natural instinct now. I don't… … I know I do it but I don't know that I do it if… … it's like breathing."

participant 6010

Participants who reported hypervigilance often reported the severe negative impact it had on their lives.

"I get home if I've been out on a long day I feel drained, physically like…"

participant 0062

"Where are you? What you doing? Because you're there physically but you're mentally scanning everything else… but you're not listening to them because you're looking at things rather than listening to what's going on… they think they're being ignored. They're not being ignored because I'm trying to concentrate on what's going on but… it does cause problems."

participant 0081

"…It does make you tired. I go to work and I feel absolutely knackered. And I find it hard to drop off to sleep cos of noises and, erm, just little noises. All the time, it's… I hate it. That's why I wanna move away from London. It's just I feel knackered all the time here, I just wanna go away to somewhere quiet."

participant 6007

"I went for coffee with a friend the other day. She said 'can you just look at me when we're talking?' I said 'I am' and she went, 'no, you're not, you're eyes are everywhere'. Um… so, it makes people uncomfortable."

participant 6010

However, a number also viewed the behaviour as having important benefits. Its is easy to see how such beliefs reinforce and maintain this behaviour

"It probably keeps me out of trouble probably more than anything… I've probably averted being run over a few times."

participant 0139

"Yeah, I see it as positive… for mine and the people I'm with's safety. But I do need to learn to stand off." participant 0265

5.2.2 *Scene-viewing task*

Due to technical difficulties with data-recording, for two participants' data were only available for 30 trials (3 blocks) of the 40 they performed; mean values were calculated in the same way for these participants. Means (and standard deviations) of the two experimental groups for all dependent eye-tracking variables and for threat ratings are presented in Table 5.2. Due to the way fixations and saccades were defined, counts of the two show perfect correlation in this task and, consequently, only saccade count is analysed. N=28 for all analyses.

Table 5.2: PTSD group means (and standard deviations) of eye-tracking parameters in the scene-viewing task.

	PTSD		Controls	
Threat Ratings	**43.14**	**(25.87)**	**21.51**	**(19.88)**
Saccades				
Number of Saccades	**23.11**	**(1.68)**	**22.51**	**(2.37)**
Saccade Duration (ms)	**39.29**	**(8.19)**	**35.08**	**(3.50)**
Fixation Duration (ms)	**285.92**	**(32.97)**	**291.30**	**(31.74)**
Scan-path length (deg)	**196.54**	**(28.56)**	**198.17**	**(17.82)**

Threat Ratings

Average threat ratings were higher in the PTSD group than in the non-PTSD participants (t(26) = 2.51, p<.05) and correlated (all correlation coefficients shown in Table 5.3a) with hypervigilance severity (Pearson's *r* = 0.54, p<.01) as well as PTSD symptomatology reported on the PDS (Pearson's *r* = 0.48, p<.05). A multiple regression analysis indicated that the two predictors together explained 34% of the variance (R^2 = 0.34, F(2,25) = 6.48, p<.01). However, only hypervigilance severity (β = 0.40, p=.05) and not PTSD symptomatology (β = -0.26, p=.19) significantly predicted mean threat ratings.

Table 5.3a: Correlation Matrix among PTSD Symptom Variables, Threat Ratings and Eye-Movement Variables in the Scene-Viewing Task

		1	2	3	4	5	6
1	**PTSD Symptom Total**□	--					
2	**Hypervigilance Severity (CAPS Total Score)**	0.55**	--				
3	**Threat Ratings**	0.48*	0.54**	--			
4	**Number of Saccades**	0.23	0.38*	0.07	--		
5	**Saccade Duration** ~	0.20	-0.03	-0.20	-0.14	--	
6	**Fixation Duration**	-0.15	-0.37*	-0.04	-0.89***	-0.09	--
7	**Scan-Path Length**	-0.13	-0.03	-0.18	0.52**	0.09	-0.50**

Table 5.3b: Correlation Matrix among PTSD Symptom Variables, Threat Ratings and Eye-Movement Variables in the Portable Eye-Tracking Task

		1	2	3	4	5	6	7
1	**PTSD Symptom Total**□	--						
2	**Hypervigilance Severity (CAPS Total Score)**	0.55**	--					
3	**Threat Ratings (relevant scenes only)**	0.51**	0.51**	--				
5	**Number of Saccades** #	-0.40*	-0.12	-0.12	--			
6	**Saccade Duration**	-0.37*	-0.28	-0.11	0.43*	--		
7	**Number of Fixations** #	-0.30	-0.11	-0.40*	-0.05	-0.06	--	
8	**Fixation Duration**	-0.01>	-0.12	0.12	0.00	0.15	0.23	--
9	**Scan-Path Length** #	-0.01>	-0.15	0.11	-0.29	-0.15	-0.39*	-0.21

□ Total score not including hypervigilance item; $ Non-Parametic Correlations; ~ Transformed variable; # Corrected for length of walk (number of frames);

Correlation significant at 0.05 level (*), 0.01 level (**), 0.001 level (***). All correlations are two-tailed. N=28.

Saccades

Contrary to the hypotheses, PTSD participants did not differ from controls in the mean number of saccades made per trial (t(26) = 0.75, p=.46). Hypervigilance severity score (CAPS total) was positively correlated with number of saccades (Pearson's *r* = 0.38, p<.05) but PTSD symptomatology was not (Pearson's *r* = 0.23, p=.25); Increased levels of hypervigilant behaviour were associated with more frequent saccadic eye movements.

Mean duration of saccades did not differ between PTSD groups[53] (t(26) = 1.73, p=.10) and did not correlate with hypervigilance severity (Pearson's *r* = -0.03, p=.88) or with PTSD symptomatology (Pearson's *r* = 0.20, p=.31).

Fixations

Mean fixation durations did not differ between PTSD groups (t(26) = 0.44, p=.67) and did not correlate with PTSD symptomatology (Pearson's *r* = -0.15, p=.46). However, hypervigilance severity correlated negatively with mean fixation durations (Pearson's *r* = -0.37, p=.05); Increased levels of hypervigilant behaviour were associated with shorter durations of fixations.

Scan-path length

Contrary to the hypotheses that scan-paths would be longer in PTSD patients than controls, no significant difference emerged between the two groups in mean scan-path length (t(26) = 0.19, p=.85). Moreover, scan-path length did not correlate with hypervigilance severity (Pearson's r = -.03, p=.89) or with PTSD symptomatology (Pearson's r = -.13, p=.52).

[53] Log transformation was necessary in order to meet parametric assumptions.

5.2.3 Portable eye-tracking of naturalistic behaviour

N=28 for all analyses. Means (and standard deviations) of the two experimental groups for all dependent eye-tracking variables (corrected for length of walk) are presented in Table 5.4.

Table 5.4: PTSD group means (and standard deviations) of eye-tracking parameters in the naturalistic eye-tracking task.

	PTSD		Controls	
Saccades				
Frequency of Saccades (/sec)	**1.57**	**(0.39)**	**1.91**	**(0.36)**
Saccade Duration (ms)	**50.52**	**(4.38)**	**52.37**	**(4.41)**
Fixations				
Frequency of Fixations (/sec)	**4.10**	**(0.46)**	**4.29**	**(0.41)**
Fixation Duration (ms)	**77.09**	**(13.99)**	**80.21**	**(13.59)**
Scan-path (deg/sec)	**24.73**	**(4.17)**	**24.54**	**(3.87)**

Saccades

Unlike in the scene-viewing task, in the portable eye-tracking street-walk task ex-servicemen with and without PTSD differed significantly in the number of saccades made (corrected for time taken to walk the route; $t(26) = 2.41$, $p<.05$). However, this effect was in the opposite direction to that hypothesised: ex-servicemen with PTSD made significantly less frequent saccades (mean = 1.57 saccades/sec) than did ex-servicemen who did not meet criteria for PTSD (mean = 1.92 saccades/sec). Frequency of saccades and hypervigilance severity were not correlated in this task (Pearson's r = -0.12, p=.55; all correlation coefficients shown in Table 5.3b) but number of saccades and PTSD symptomatology showed a negative correlation (Pearson's r = -0.40, p<.05).

Ex-servicemen with and without PTSD did not differ in mean *duration* of saccades made ($t(26) = 1.10$, p=.28) and saccade duration did not correlate with hypervigilance severity (Pearson's r = -0.28, p=.14). However, saccade duration was negatively correlated with PTSD symptomatology (Pearson's r = -0.37, p=.05).

Fixations

No group differences were observed for either mean duration of fixations (t(26) = 0.59, p=.56) or frequency of fixations (t(26) = 1.17, p=.25) and neither of these variables correlated with hypervigilance severity or PTSD symptomatology (all p>0.1, all Pearson's *r* (absolute value) < 0.3).

Scan-path Length

It was hypothesised that scan-paths would be longer in PTSD patients than controls. However, no significant difference emerged between the two groups in mean scan-path length (t(26) = 0.13, p=.90). Additionally, scan-path length did not correlate with hypervigilance severity (Pearson's *r* = -.15, p=.46) or PTSD symptomatology (Pearson's *r* < 0.01, p=.99).

5.3 Discussion

The two eye-tracking procedures reported aimed to shed new light onto the clinically-reported symptom, hypervigilance. It was hypothesised that ex-servicemen with posttraumatic stress disorder (PTSD) would show a pattern of 'hyperscanning' and that the degree of this behaviour would be related to self-reported severity of the clinical symptom hypervigilance. Ex-servicemen took part in both a laboratory-based eye-tracking procedure (where they were asked to freely view street scenes) and a naturalistic task (where they walked a number of London streets whilst wearing a portable eye-tracking device). As expected, participants reported hypervigilance symptoms which particularly occurred when walking unknown streets. However, reports of severe hypervigilance were not confined to the PTSD group and occurred in a significant proportion of the non-PTSD control group. In line with patient reports, it was hypothesised that PTSD patients (relative to trauma-exposed controls) would show hyperscanning, evidenced by; 1) more frequent saccades and fixations, 2) with fixations of shorter durations and 3) increased scan path length.

5.3.1 Scene-viewing task

Average threat ratings were higher in the PTSD group than in the non-PTSD participants. However, only hypervigilance severity (and not PTSD symptomatology) significantly predicted mean threat ratings suggesting that hypervigilance specifically rather than PTSD symptoms generally, results in elevated feelings of threat.

Although they rated the scenes as significantly more threatening, the PTSD group did not show any evidence for hyperscanning behaviours when compared to the non-PTSD group. One explanation for this might be that the groups had a number of important similarities which may have outweighed their diagnostic differences. A large number of non-PTSD participants met criteria for hypervigilance and all participants had experienced combat traumas and also been through military training; all of these factors may have meant that any PTSD-related eye-movement differences were overshadowed by general traits of the sample as a whole. Follow-up work could aim to recruit age-matched non-military controls in order to further investigate this proposal.

Alternatively, PTSD-group differences may not have emerged because eye-movements are closely tied not to the disorder as a whole but to a subset of symptoms, or a single symptom. Certainly, hypervigilance severity (but not PTSD symptoms) was positively correlated with number of saccades and negatively correlated with the duration of fixations; participants reporting more severe hypervigilance made a greater number of saccades and made fixations of shorter durations. These observations were in the directions hypothesised and support a measurable hyper-scanning eye-movement behaviour which corresponds to reported hypervigilance. However, not all the hypotheses were supported; no relationship between reported hypervigilance and length of scan-paths was observed. Additionally, since severity of other symptoms was not assessed, it is possible that hyperscanning is also related to other symptoms and not to hypervigilance alone.

Whilst attention and saccades are accepted as being largely intertwined, it is not clear whether components of the two can be directly equated. Previous work has suggested that vigilance for threat can be measured by speed of saccades to threat location and that difficulty disengaging from threat might be represented by dwell time (or duration of fixations) in the vicinity of threat. Conversely, initial fixations to threat that last for only a brief period of time have been reported as support for a vigilance-avoidance pattern of attention in anxiety (e.g. Pflugshaupt et al., 2005). The present study is unusual amongst the anxiety literature in not utilising emotional stimuli and so cannot be directly compared with this previous work. It is possible that increased frequency of saccades represents a compulsion to “check” (i.e. to fixate) new locations for threat and/or a persistent revisiting of previous locations. More frequent saccades may also reflect a repeated avoidance of fixated locations. Future work should attempt to separate these possibilities. Also, discovering how much information is extracted from scenes during different viewing patterns would certainly be informative.

Duration of fixations has sometimes been referred to as dwell time and linked to the concepts of delayed disengagement and avoidance from the attentional bias literature. The finding in the scene-view task that increased levels of reported hypervigilance were associated with fixations of shorter durations fits with an avoidance account of attention in anxiety.

Overall, the findings from the scene-view task suggest that subjective experiences of hypervigilance can be captured by objective laboratory-based eye-tracking methodologies. Given that hypervigilance has been reported in the literature as the first symptom to arrive in delayed-onset PTSD (Andrews et al., 2009) and is part of the cluster of hyperarousal symptoms which predict subsequent PTSD onset (Marshall et al., 2006; Schell et al., 2004), discovering a new method for measuring this symptom potentially offers another tool for early identification of trauma-exposed individuals who are at risk of subsequent PTSD development.

Given this evidence, the participants who did not meet criteria for PTSD but reported severe hypervigilance are possibly at risk for developing further symptoms, or even delayed-onset PTSD. Alternatively, it is possible that hypervigilance is a distinct feature of the military population under study here who have often received training with vigilance components. Certainly, many of the participants themselves linked their hypervigilant behaviour to their military training.

> *"It started I think when, in the army really… Yeah, it's just, erm, drummed into you so much … Yeah, it's just like some, a habit"*
>
> participant 0062
>
> *"… with what happened with Northern Ireland, with not knowing who it was, where it was gonna happen or why it was gonna happen, erm, it's never knowing where the threat was coming from so you become a lot more observant to what was going on… Even though I'm not involved in the military environment, you've still got that in your mind that you're looking out for things."* participant 0081

It is unclear whether other trauma-exposed populations contain a subset of individuals who report enduring hypervigilance without full PTSD; this would be an area ripe for future investigation given the hypothesised links between threat-biased attentional processing and emotional reactivity to stressors (e.g Mathews & MacLeod, 2002).

5.3.2 Portable eye-tracking of naturalistic behaviour

Unlike in the laboratory-based scene-viewing task, the pattern of results in the naturalistic eye-tracking task did not support the hypotheses. PTSD participants were observed to make *less frequent* saccades than non-PTSD participants (not *more* frequent as hypothesised) and, accordingly, PTSD symptomatology correlated negatively with saccade frequency. PTSD symptomatology also correlated negatively with saccade duration; participants who reported more severe PTSD symptoms made saccades of shorter durations. Hypervigilance severity was not related to either saccade frequency or duration.

This set of results is in contrast to those of the scene-viewing task. It was hypothesised that any PTSD group or hypervigilance-related differences would be most clearly observed in the naturalistic task since this most closely equates to the settings in which patients report experiencing severe hypervigilance. The results of the present study show that in a situation where hypervigilance is reported as present, a pattern of less frequent saccades of shorter duration is seen with increasing PTSD symptomatology. However, this pattern of eye-movements is not related to reported hypervigilance suggesting that it is perhaps capturing a different aspect of PTSD than hypervigilance. One possibility would be that this pattern of eye-movements instead relates to avoidance behaviours. Avoidance (or reminders of the trauma and of thoughts and feelings) is part of the diagnostic criteria for PTSD (American Psychiatric Association, 2000) and work with social phobics has previously shown that degree of oculomotor avoidance was related to social phobia symptom severity (Horley et al., 2004). Indeed, in that study Horley et al. (2004) used stimuli (emotive and neutral faces) which directly corresponded to patients' foci of worry, just as in the present study, a street-walk task was selected to reflect a reported hypervigilance-provoking situation.

Another possible explanation is that the street-walking task led to suppression of the eye-movement behaviours which were recorded in the laboratory. Suppression of attentional bias to threat has been reported before in PTSD patients under conditions of high state anxiety (Constans et al., 2004) and it is possible that a similar phenomenon occurs for hypervigilance. However, this is completely counter to what patients report; hypervigilance is reported by patients as being at a peak when walking around in public spaces. Moreover, this does not explain why a relationship in the opposite direction was seen rather than no relationship at all.

A practical limitation of the paradigm should also been borne in mind when interpreting the findings. Head-mounted equipment and the analysis programme used allows for eye-movement analysis (with the Sly-Tracker software) and gaze-content analysis but, due to the combination of head and body movements as the participant walks, it is not possible to calculate size of head movements solely from the videos recorded. It is possible, therefore, that eye-movements in this task do not fully capture hypothesised hyper-scanning behaviour. Static, laboratory-based equipment does not have this limitation since head position is fixed at all times. However, laboratory-based eye-tracking paradigms do not reflect eye-movements in the real world and, as such, the novel naturalistic eye-tracking results reported here are a vital adjunct to the laboratory-based scene-viewing task.

Future work might try to investigate whether differences seen in eye-movements in the present study are context-dependent. Stimuli and location for the present study were selected to be *objectively* without threat but representative of situations in which patients report increases in *subjective* threat levels. A baseline condition in which eye-movements are recorded in a situation which is both objectively and subjectively threat-neutral would shed light upon the outstanding query of whether the findings reported in the present study reflect a general context-independent change in eye-movements or a specific context-dependent change related to increase in subjective threat experience.

5.3.3 Conclusions

Evidence from the scene-viewing task suggests that free-viewing of neutral street scenes provides a valid method for measuring the severity of the PTSD symptom ‘hypervigilance’. Understanding whether reported hypervigilance reflects the *actuality* of patients’ altered behaviours or whether it reflects patients’ altered *interpretation* of behaviours may have therapeutic value. For example, attention bias modification paradigms offer great promise for patients who show vigilance for threat (Bar-Haim, 2010; Browning et al., 2010; Hakamata et al., 2010) but are unlikely to yield significant emotional impact for patients who *feel* under threat and are interpreting their own *unchanged* behaviours in a new threat-monitoring light. The results from the present study suggest that reported hypervigilance has measurable eye movement correlates, which can be captured objectively using a laboratory-based free-viewing eye-tracking task in the absence of actual threat.

By contrast, in the naturalistic street-walk task, the PTSD group showed less frequent saccades of shorter duration than the non-PTSD group. In this task, no relationships were observed between reported hypervigilance and eye movements. This pattern of eye movements may be best understood as representing avoidance behaviours.

The two paradigms reported here are both novel in their design and, whilst having great ecological validity, it is unclear at this stage precisely which cognitive processes they are best suited to measuring. The present study did not investigate the relationship between preferential threat processing (such as has been shown in dot probe and emotional Stroop tasks) and hyperscanning in the absence of objective threat. These two behaviours are often used synonymously in the literature or at least assumed to have a strong relationship; understanding how these two processes are related would be of interest for future research. Additionally, subsequent analysis of the street-walk dataset by Sly-Tracker could extract gaze-location frame-by-frame by combining pupil location with the 5-point calibrations performed at both the start and the end of the procedure. Analysis of gaze movements may yet yield very different conclusions to the analysis of eye movements.

Finally, this study's novel methodology and the observed discrepancy in findings between the two eye-tracking paradigms highlights the importance of caution when generalising from laboratory measures to real-world behaviour. The increasing use of eye-tracking methodologies to derive attentional processes in laboratories should not detract from the caution needed in drawing conclusions before behaviour is measured in more real-world settings.

Chapter 6: Discussion

Biases in processing of salient stimuli are hypothesised to underpin psychopathology in a number of domains. In anxiety, biased attention is posited by a number of influential theories as being important in both aetiology as well as maintenance of the disorder. The work in this thesis aimed to address a number of unresolved questions about the nature of biased attentional processing of threat and the links between biased attention processes and conscious experience of anxiety.

I begin by summarising the findings of each of the experimental chapters before discussing their relevance to each of the hypothesised stages of attention bias introduced in chapter 1. I will then discuss the connectedness of these stages and how alterations at more than one stage may result in altered emotional processing. Next I introduce the idea of regulation of emotion through biases in attention and try to shed light onto how this behaviour might be altered in individuals with anxiety disorders. Finally limitations and clinical implications of my experimental work will be discussed as well as some suggestions for future research.

6.1 Summary of findings

There was some debate in the literature around whether engagement or disengagement stages of attentional bias were crucially altered in anxious individuals. I designed a novel task which aimed to differentially assess these two stages in high and low anxious individuals, and also to independently modify the two stages in a training protocol. Chapters 2 and 3 report these studies. Findings suggested that this new task tapped a component of threat-processing which was common across all participants irrespective of trait anxiety level. The importance of considering both content and location attentional shifts was highlighted.

Following from these findings that more than one stage of attentional processing is crucially altered in anxiety, I investigated whether pre-conscious processing also showed anxiety-related variation. Chapter 4 investigated pre-conscious processing of non-emotional faces which varied in dominance and trustworthiness traits. Findings demonstrated that personality traits in faces are processed at a pre-conscious stage and that individual differences in this early processing are linked to observers' own reported personality traits. Moreover, war veterans with post-traumatic stress disorder (PTSD) showed alterations in processing of submissive faces.

The PTSD symptom 'hypervigilance' is often viewed as the (conscious) clinical manifestation of (non-conscious) attentional bias towards threat. However, patient reports of hypervigilance differ fundamentally from the cognitive psychology concept of attentional bias. Chapter 5 aimed to capture the reported experience of the symptom using eye-tracking technology in both a laboratory and real-world setting.

6.1.1 Chapter 2

In chapter 2 I introduced a novel attention bias assessment task with the intention of addressing a number of the limitations of the widely-used dot-probe task. The task aimed to independently assess engagement and disengagement components of attention bias whilst also investigating the contribution of shifting or maintaining location of attention. Experiment 1 reported a comparison of the performance of high and low trait-anxious individuals on the task; experiment 2 used a modified version of the task as a training paradigm and investigated the effect on emotional reactivity of separately modifying engagement and disengagement in mid-anxious individuals.

Experiment 1 revealed that when participants maintained the location of their attention they were *slower* to move on (disengage) from negative content that neutral. By contrast, when participants changed spatial location concurrently, they were *faster* to disengage from negative content relative to neutral. On engagement trials, participants were slower to engage with negative stimuli relative to neutral stimuli when required to *change* spatial location, but did not show this valence-related difference when required to *maintain* location of attention. These behaviour patterns were evident in all participants irrespective of trait or state anxiety level. The most plausible explanation for these findings seems to be that disengagement from content is *helped* by concurrently moving the spatial location of attention (and hindered by being forced to maintain location of attention).

Experiment 2 in this chapter modified the bias assessment task and attempted to train one group of participants to engage less with negative images and one group to disengage more (a final group were not trained to do either of these things and performed trials at random). After training participants watched a trauma-analogue film and kept a diary of intrusive thoughts for the subsequent week.

There were some indications that utilising the novel attention bias task as a training task resulted in differences in processing; primarily, the two training groups showed a substantially reduced state-anxiety change to the trauma film. However, this state-change to the stressor did not lead to group differences in intrusions of the film so that it was not possible to draw conclusions about this bias training as a likely intervention for anxiety response to trauma. Additionally, there was no measureable difference in induced biases between training groups after the training. Consequently, it was not possible to link the group differences in emotional processing directly to attention bias modification. The fact that both training groups showed state anxiety reduction suggests that both engagement and disengagement processes play a role in causing anxiety and that altering either one has an impact upon emotional reactivity.

6.1.2 Chapter 3

In chapter 3 I aimed to replicate and extend the findings of experiment 1 in chapter 2. One block of the task was identical to chapter 2 except for the stimuli utilised (threatening rather than negative stimuli); a second block did not require participants to engage with the semantic content of stimuli but was otherwise unaltered. Like in experiment 1 of chapter 2, groups of high and low trait-anxious individuals were recruited and their performance on the bias task compared.

The findings of the semantic (replication) block partially (but not fully) replicated those of the previous study. Once again no differences emerged between the anxiety groups and there was partial replication of the overall pattern of effects from chapter 2; the three trial types (neutral, engage and disengage) were differentially affected by moving or maintaining location of attention. This disparity between attentional processes with the two sets of stimuli was suggested to reflect either well-rehearsed responses to linguistic stimuli or a difference between processing of threatening and generally negative stimuli.

In the block in which participants were required to make judgements about the structural features of stimuli (instead of engaging with semantic content) a different pattern of biases was observed. Reaction times showed only a main effect of moving location of attention (trials which required a move in location took longer) but valence of stimuli did not alter response latencies. This striking effect of instructional set shows that the participants were highly effective at ignoring valenced stimuli when they were not required by the task to engage with the meaning of the stimuli.

One limitation which must be discussed is that of the baseline condition in the experiments in both chapters 2 and 3. The neutral trials which form the baseline condition always presented two entirely new stimuli in the second screen. This condition works well as a comparison for the engage trials which also always presented two new stimuli in the second screen. However, for the disengage trials this baseline is inappropriate since in those trials the negative stimulus from screen was re-presented in screen two. This limitation potentially alters the interpretation offered above for the results of the disengagement trials (speeded disengagement on move trials, slowed disengagement on stay trials). Instead of these effects being explained by valence of stimuli, it is possible that this is a novelty effect: speeded engagement with novel stimuli on move trials, slowed engagement with novel stimuli on stay trials. Future work should use a more appropriate baseline condition for analysis of the disengage trials.

6.1.3 Chapter 4

Chapter 4 reports a series of experiments which set out to investigate pre-conscious processing of personality traits in face stimuli. This was of interest not only because traits (trustworthiness and dominance) were selected which have threat-relevance (and amygdala associations) but also because an individual differences approach extends the cognitive-experimental approach from the attention bias and anxiety literature. I aimed to investigate whether individual differences in personality had measurable correlates in preconscious processing in the same way that individual variation in psychopathology symptoms are hypothesised to.

Continuous Flash Suppression (CFS) was used to keep stimuli from awareness and participants were required to make a forced-choice decision as soon as stimuli broke through awareness, giving a measure of how long stimuli take to reach consciousness. Variations in pre-conscious face processing were shown to be explained by observer as well as stimulus differences.

Variations in trait levels of trustworthiness and dominance in face stimuli resulted in differences in pre-conscious processing (experiment 1), which were replicable and not due to feature processing alone (experiment 2), and which showed inter-observer differences which were related to self-reported personality traits (experiment 3). Trustworthiness showed a U-shaped relationship with time-to-emergence such that both trustworthy and untrustworthy faces took longer to break through CFS than did neutral faces. Dominant faces also took longer to break through CFS than did neutral. It was suggested that these findings reflect either a form of mental freezing in the presence of threat-relevant traits or suppression of these stimuli.

This quadratic pattern of results was replicated for trustworthiness in an experiment (experiment 4) with war veterans. One group of veterans had PTSD; no difference in pre-conscious processing of trustworthiness was found between war veterans with and without PTSD. However, a lack of freezing for dominant faces was seen in British war veterans (with and without PTSD) and, moreover, an opposite pattern of speeded break-through to awareness for submissive faces was seen in veterans with PTSD.

6.1.4 Chapter 5

In PTSD, like in other anxiety disorders, there is evidence for threat biases in attention (Bryant & Harvey, 1997). Moreover, biases predict later PTSD symptomatology in trauma-exposed individuals (Wald et al., 2011b). The PTSD symptom 'hypervigilance', hypothesised to be the clinical manifestation of attentional bias towards threat, both arrives first in PTSD with a delayed onset (Andrews et al., 2009) and is part of the (hyperarousal) cluster of symptoms which predicts the full onset of the disorder (Schell et al., 2004; Marshall et al., 2006).

In chapter 5 I aimed to capture this clinical symptom using behavioural methodologies. I reported two experiments which utilised eye-tracking technology; one task was laboratory based and required participants to freely view photographs of street scenes, the second task required participants to leave the laboratory and tracked eye-movements as they walked London streets wearing a head-mounted device.

The laboratory task revealed that eye-movements during free-viewing of relevant settings is a correlate of self-reported severity of the PTSD symptom hypervigilance. Group membership of participants (PTSD, non-PTSD) did not differentiate any eye-movement behaviours in this task. Instead, reported hypervigilance was associated with a number of hyper-scanning measures (more frequent saccades and shorter fixation durations).

By contrast, in the naturalistic street-walk task, the PTSD group showed less frequent saccades. Saccade duration was also related to PTSD symptomatology in that the greater the number of PTSD symptoms reported by patients, the shorter the durations of their saccades. These relationships between PTSD and natural eye-movements are in the opposite directions to that hypothesised from patient reports of their behaviours. Additionally, in this naturalistic task in contrast to the laboratory task, no relationships were observed between reported hypervigilance and eye movements. Discrepancies between the two tasks remind us of the need to bear in mind both the restrictions and the advantages of laboratory-based paradigms.

6.2 Stages of Attention Bias

Four conceptually distinct phases of attention commonly referred to in the attention bias literature were outlined in chapter 1 and the work in this thesis has touched on all of these. In order of assumed occurrence they are: 1) *orientation* towards a stimulus, 2) *engagement* with the stimulus, 3) *disengagement* of attention from the stimulus, 4) *avoidance* of the stimulus. Cognitive theories of anxiety propose that anxious individuals show altered processing at one or more of these stages and experimental support exists for altered processing at each stage. However, there is disagreement about which stages are crucially altered and which only incidentally.

6.2.1 Orientation

Both behavioural and brain imaging studies have shown that threat prioritisation occurs at a pre-conscious stage of processing and that activation of the amygdala appears to be mediated sub-cortically and independently of attention (Ohman, 2005). In anxious individuals, even unattended threat-related stimuli result in an increased amygdala response whilst low anxious individuals only show this response to stimuli which are attended (Bishop et al., 2004). This finding is consistent with modulation by anxiety of the output of a pre-attentive threat evaluation mechanism as postulated by a number of cognitive theories of anxiety (Mogg & Bradley, 1998; Mathews & Mackintosh, 1998). However, Bishop (2007) suggests that since anxiety only modulates the amygdala response to threat when perceptual load is low (Bishop et al., 2007), the influence of anxiety might occur subsequent to an initial stage of perceptual competition.

Bishop (2007) proposes a neuro-cognitive model of anxiety-related bias in selective attention in which threat-relevant stimuli gain an advantage in pre-attentive processing only in state-anxious individuals. Consequently, this advantage for threat stimuli would be expected more commonly in high trait-anxious individuals who are prone to frequent elevated state anxiety.

Evidence presented in chapter 4 (continuous flash suppression experiments) showing that threat-related traits are extracted pre-consciously appears to support the existing literature. Moreover, the finding that personality traits are related to pre-conscious processing of threat-relevant traits in faces supports the hypothesis that individual differences exist in pre-attentive threat advantage. However, pre-attentive processing does not appear to be restricted solely to imminent threat indicators but also extend to facial features indicative of trustworthiness and dominance.

These social dimensions are not traits which have been considered previously in work on psychopathology but this work shows that such investigations may yield interesting findings in future work. Certainly, understanding individual differences in perception of trustworthiness in others has intuitive merit; first because the ability to build and maintain an social support network is known to be protective against psychopathology (Kessler et al., 1985), and second because interpersonal trust aids therapeutic alliance (Ackerman & Hilsenroth, 2003) which is related to improvements in efficacy of psychotherapy (e.g. Westra et al., 2011). Furthermore, trust may be particularly relevant to specific groups such as patients with post-traumatic stress disorder following interpersonal trauma.

6.2.2 Engagement & Disengagement

Facilitated engagement with, and delayed disengagement from, threat in anxious individuals have both received ample support in the literature (for reviews see Bar-Haim et al., 2007; Yiend, 2010). Whilst these viewpoints were once regarded as competing, there is now convergence upon the idea that time-course of paradigms is vital in dictating which process is captured (Koster et al., 2007) and that anxiety-related alterations exist at both of these stages of processing[54]. The study in chapter 2 which investigated the consequences of training engagement and disengagement separately supports this notion; both types of modification resulted in emotional processing changes. In this study I showed that training participants either to engage less with negative content, or to disengage from that content, resulted in a reduced state anxiety

[54] Currently in the attention bias literature focus seems to have shifted away from engagement-disengagement debates towards an idea of vigilance followed by avoidance of threat as being the signature attentional pattern of anxious individuals (e.g. Onnis et al., 2011, and see section 6.2.4 for further discussion).

change to a subsequent stressor. Hypothetical[55] follow-on work might attempt to induce the opposite biases and investigate whether this results in the hypothesised *increase* in emotional reactivity.

The studies reported in chapters 2 and 3 (attentional bias assessment and training task) did not show evidence for either generally speeded engagement with, or generally slowed disengagement from, negative stimuli. On valid engagement trials where speeded response to negative items has been shown previously in high anxious individuals, no difference was seen in response times to negative and neutral stimuli in the high or low trait anxious. On invalid disengagement trials, where slowed response to negative items has been shown previously in high anxious individuals, speeded response to negative stimuli was shown instead (in all participants). Critically, these studies showed that ideas of disengagement need to be dissected into questions about disconnection from content and questions about location shifts in attention, since these covert and overt attentional processes are not mapped one-to-one. Previous work has always conflated disengagement from content with a shift in location of attention (and difficulties disengaging from content with maintained location) but my work shows that disengagement from negative (compared to neutral) content is different in one direction (faster) when a location shift is required and different in the other direction (slower) when location of attention must be maintained.

6.2.3 Avoidance

Avoidance of relevant stimuli, as assessed by either response latencies on dot probe tasks or eye-movements, has been shown in social anxiety (e.g. Chen et al., 2002; Horley et al., 2003; Mansell et al., 1999; Moukheiber et al., 2010), spider phobia (Pflugshaupt et al., 2005) and PTSD (Bar-Haim et al., 2010; Wald et al., 2011a; 2011b) in studies which all displayed stimuli for longer durations (500ms and above). Additionally, findings from the emotional Stroop task have been suggested to reflect attempts in anxious individuals to suppress (a type of avoidance strategy) threat meaning (Deruiter & Brosschot, 1994). Similarly, chapters 2 and 3 provided evidence for avoidance of negative and threat stimuli (stimuli exposed for around 1000ms),

[55] Hypothetical only as the ethics of increasing anxious response to trauma are dubious.

although this was shown to be present in *all* participants and not just those with elevated levels of anxiety.

Whilst avoidance has been generally discussed as maladaptive in the anxiety literature, *adaptive* avoidance has been reported previously in low anxious individuals (MacLeod et al., 1986; MacLeod & Mathews, 1988; Bryant & Harvey, 1997; Yiend & Mathews, 2001; Mogg et al., 1992; 1995b; 2000c; Wilson & MacLeod, 2003; Koster et al., 2006) and it has been suggested that it is the timing of avoidance and not avoidance per se which is indicative of anxiety (Onnis et al., 2011).

Suppression, one form of avoidance, is very much implicated in anxious response to emotional stimuli (Salters-Pedneault et al., 2004). Evidence from the continuous flash suppression tasks presented in chapter 4 suggest that suppression responses may begin pre-attentively and that individual variation in the tendency to suppress information is related to individual differences in associated personality traits. Rather than being solely the final stage in attentional processing, the effect of avoidance processes should be considered at multiple stages.

6.2.4 Connections between stages of bias

Whilst the stages of processing outlined above are conceptually distinct, they are largely confounded in practical terms and difficult to truly measure in isolation. Each stage of processing is somewhat dependent upon the last and altered processing at any stage may have knock-on effects for later stages even if those later stages are unaffected otherwise by anxiety. For example, delayed disengagement may not result directly from anxiety itself but may instead reflect facilitated engagement (and associated deeper processing of stimuli). Generally work in the attention bias and anxiety literature has attempted to separate the processes by controlling stimuli exposure durations in order to investigate early or late processing or by looking at time-course (e.g. Koster et al., 2007). Work investigating the interdependence between different stages of processing has been minimal even though theories proposing relationships have existed for some time.

The vigilance-avoidance hypothesis posits that anxiety is characterised by an initial vigilance towards threat followed by a subsequent effortful avoidance of threat in order to minimize discomfort (Mogg & Bradley, 1998; Mogg et al., 2004) and these two opposing biases have indeed been demonstrated at different temporal lags. However, the exact nature of the relationship between the two is unclear. Onnis, Dadds & Bryant (2011) used eye-tracking methodology to show vigilance-avoidance patterns for conditioned aversive stimuli in high trait-anxious individuals and the opposite pattern (avoidance-vigilance) in low-trait anxious. This was achieved using the standard dot-probe methodology with short (200ms) and long (500ms and 800ms) exposures of stimuli. The novel part of this study is that they also found that the magnitude of initial bias towards threat was negatively correlated with magnitude of subsequent bias away from threat, indicating a mutual relationship between the two stages.

This interdependence between vigilance and avoidance processes fits well with neuroscientific accounts of anxiety in which the amygdala is hyper-responsive to threat (vigilance) and the anterior cingulate and prefrontal cortex do not adequately down-regulate amygdala reactivity (Bishop, 2009; Shin, 2009).

Eye-tracking methodologies have already yielded interesting insights and offer promise for investigating attentional deployment over an extended time period. Work reported in chapter 5 found that number of saccades (and fixations), as well as fixation durations when viewing non-emotive scenes, were related to self-reported level of hypervigilance, possibly reflecting a pattern of hyperscanning. However, the role of avoidance in this pattern was not discussed. If anxiety is indeed characterised by vigilance-avoidance patterns then hyperscanning could reflect cyclical implementation (i.e.vigilance-avoidance-vigilance-avoidance…). However, avoidance is not *necessarily* involved in hyperscanning and, alternatively, may only occur when actual threat is encountered. Investigating patterns of eye-movements in stressful as well as neutral settings, with valenced and non-valenced stimuli, seems pertinent.

Amongst a military population (or other threat-prone population) understanding tendency to avoid threat is particularly crucial; a tendency to avoid threat locations could prove life-threatening in high-threat situations such as on the battlefield. Understanding how attention processes *during* threatening situations differ from attentional patterns *following* threat is also important in this population. A large proportion of the literature on PTSD has focussed on military populations. Whilst this is both interesting and necessary, it is possible that military populations are not representative of the general population in a number of ways. Of particular relevance here is the fact that military training may impact upon attentional patterns in a way which pervades beyond service time and is not usurped by subsequent development of psychopathology.

6.3 Emotion Regulation

Emotion regulation has been variously defined in the literature and is sufficiently vague to encompass a broad range of behaviours. Here I use the phrase to denote self-regulation (as opposed to regulation by forces outside the self) *of* emotion (as opposed to *by* emotion). This is still a broad definition and regulation of emotion can be both automatic and voluntary, both conscious and non-conscious, and can have effects at one or more points in emotion generation. Emotions unfold over time and emotion regulation can act at any point to increase, decrease or simply maintain emotional response, depending on an individual's goals.

Emotion regulation has been proposed to be essential for mental health (Gross & Munoz, 1995). It is important to point out that emotion regulation strategies which are 'good' or appropriate in one setting may be 'bad' or maladaptive when applied in another setting or to another emotion. Consequently, it is important to consider not only the regulation of emotion but also setting and the emotion itself.

Individuals with anxiety disorders report impaired emotion regulation (Amstadter, 2008) and clinical criteria for anxiety disorders (as well as much other psychopathology[56]) implicate emotion regulation difficulties (American Psychiatric Association, 2000). Ironically, some emotion regulation strategies (including avoidance) employed by anxious individuals serve only to exacerbate emotional experiencing (Salters-Pedneault et al., 2004). Worry and high levels of comorbid substance use

[56] Over 50% of Axis I disorders and 100% of axis II disorders implicate emotion regulation difficulties (Gross and Levenson, 1997; cited in Amstadter, 2008).

commonly seen in anxious individuals have been suggested to reflect attempts at emotion regulation (Borkovec et al., 2004; Tull et al., 2011a).

6.4 Attention Bias as Emotion Regulator

Gross (1998; Gross, 2007) defines five families of emotion regulation processes: situation selection, situation modification, attentional deployment, cognitive change, and response modulation. According to Gross, the first four of these processes are best considered *antecedent-focused*, in that they occurred before full emotional response has occurred. These are contrasted with *response-focused* emotion regulation, which occurs after responses are generated (Gross & Munoz, 1995). According to Gross, attention deployment might be considered an internal version of situation selection and both distraction and concentration (the two major strategies discussed by Gross) involve internal redirection of attention. However, it is not specified at which stages of attentional processing this deployment change might act. Although attentional deployment as defined and discussed by Gross is not sufficiently detailed to serve the purposes of the present thesis, it is helpful to consider this family of emotion regulation strategies as encompassing a number of attentional processes which can be applied at any stage of the emotion generation process (Koole, 2009).

Avoidance following vigilance in repressors has been suggested to be part of an emotion regulation behaviour which serves to reduce conscious experience of (physiologically measurable) anxiety (Derakshan et al., 2007). In individuals who experience high levels of anxiety it seems possible that avoidance may also be an attempt to effect the same down-regulation of physiological responsivity. In chapter 2, I discussed the idea that the act of shifting attention away from the *location* of negative stimuli facilitated disengagement from the *meaning* of the stimuli. This pattern of behaviour potentially reveals a relationship between attentional bias behaviours and emotion regulation goals. My findings in that chapter suggest that this is a mechanism which is general across all individuals, although the slowed response latencies in high anxious individuals may reflect the fact that this process requires effortful control for these individuals.

Attentional bias behaviours have been linked to emotion regulation goals by other authors (e.g. Becker & Detweiler-Bedell, 2009). Isaacowitz and colleagues (2008) reported that in older adults gaze preference for more positive stimuli is increased by the induction of a negative mood state. This mood-*in*congruent effect is suggested to reflect the emotion regulation goals of older adults in this task (Isaacowitz et al., 2006; Isaacowitz et al., 2009; Isaacowitz & Choi, 2011). In younger adults the opposite pattern of behaviour was seen; induction of negative mood led to participants looking more at negative faces whilst induction of positive mood led to increased looking at positive faces.

Specific to trauma, Bardeen & Reed (2010) reported that individuals who report high levels of attentional control show a greater reduction in emotion in the 30 minutes following a trauma retelling. Additionally, Tull et al. (2011b) utilised a dot-probe methodology to measure attentional bias and showed that cocaine addicts with PTSD showed bias towards cocaine cues (over neutral) after hearing a narrative of their trauma, whilst after a neutral narrative they show bias away from cocaine cues. Cocaine addicts not diagnosed with PTSD showed the reverse pattern. Tull et al. suggest that this shows different uses for cocaine in the two groups; the PTSD group orient towards cocaine after the trauma reminder as an emotional regulator whilst non-PTSD cocaine addicts do not orient towards cocaine as a distress moderator. This argument was supported by the fact that degree of reported distress after the trauma script in the PTSD group successfully predicted the size of the attentional bias towards cocaine cues.

These two studies show that attentional processes can be used to cope with emotion-eliciting events. Rothermund et al. (2008) demonstrated that automatic affective counter-regulation can also be utilised in goal-pursuit. In their study, participants could either win money (positive outcome focus) or avoid losing money (negative outcome focus) depending upon their performance on a flanker task. Interference of negatively valenced distracters in the flanker task was greater in blocks where money could be won whilst positive stimuli showed greater distracter effects in blocks with a negative outcome focus. This incongruency effect demonstrates that attention can be automatically biased by outcome foci.

Whilst this finding demonstrates that goal-pursuit can alter attentional processing, it is unlikely to offer huge amounts of hope to anxiety researchers or patients. Colin MacLeod (pg 67, MacLeod & Bucks, 2011) suggests that the "…inordinate severity of disability that characterises clinical anxiety patients may result from their failure to employ strategically controlled patterns of selective attention to mitigate the emotional impact of automatic vigilance for threat (Bar-Haim et al., 2007; MacLeod & Rutherford, 1998)". Future work could investigate whether high-anxious individuals show goal-pursuit bias like that demonstrated in Rothermund et al (2008); understanding whether anxious individuals show ability to down-regulate attention in this fashion could inform ideas about the possibility of therapeutic success for interventions which require top-down regulation of attentional responses by anxiety patients.

6.5 Strategic and Automatic Processes

Cognitive-experimental methodologies have generally been designed to bypass reliance on introspective access to information processing (MacLeod, 1991). Whilst anxiety disorder patients who report information processing difficulties (such as hypervigilance reported by PTSD patients) must clearly be aware of these biases in some sense, other patients and participants with elevated levels of trait anxiety may not be. Rather than investigating issues of conscious access to biased processing, the focus in the attention bias literature has instead been upon whether the stimuli presented are available to conscious awareness.

Attention bias effects seem to be stronger for subliminally presented stimuli in the dot probe task (Bar-Haim et al., 2007). There is some discussion about strategic stages of processing in the attention bias literature but clearer definition of this term is required since all stages of biased processing seem to happen automatically[57]. Rothermund et al.'s work described above suggests that biases in processing can respond to goal-pursuit aims. Additionally, there is some evidence that attentional processing is consciously controllable (Krebs et al., 2010).

[57] However, Onnis et al (2011) suggest that criteria for automaticity (Schneider & Shiffrin, 1977) are actually violated at all stages. Note that non-automaticity does not mean that these processes are fully under volitional control or can be considered strategic.

Work presented in this thesis has provided evidence of non-conscious threat processing (chapters 2 and 3) which was not anxiety-related. Additionally, hypervigilance-related changes in conscious attentional patterns were observed (experiment 1, chapter 5) which were independent of threat presence. Future work could investigate the interplay between conscious and controllable (or non-conscious and automatic) processes. Since automatic emotion regulation is associated with advantages over strategic emotion regulation (Koole, 2009) it is clinically relevant to discover whether conscious effortful strategies could become automatic with repetition or training. A better understanding of the relationship between top-down and bottom-up attentional processes in anxiety will be necessary.

6.6 Beyond the dot probe

The dot probe task is widely used in the attentional bias literature and has shaped ideas about attentional processing in anxiety. It addresses limitations of the emotional Stroop (which dominated previously) but also has a number of limitations of its own which I have outlined previously. Reports from the field are that effects are sometimes hard to replicate and one wonders if positive publication bias is preventing the true picture from being evident; perhaps the attentional biases reported so consistently in the literature with the dot probe task are only a part of the story. Certainly, biases seem to alter according to setting (Bar-Haim et al., 2010; Constans et al., 2004), as well as being dependent upon timings (Onnis et al., 2011) and instructional set (chapter 3).

In my haste to steer away from an over-reliance on the dot probe I did not attempt to do any work using dot probe paradigms. In hindsight I think many of my findings would have been strengthened had I been able to compare participants' performances on dot probe tasks with their performance on the novel tasks I report in the thesis. For example, findings from the novel attention bias assessment task reported in chapters 2 and 3 could have been more confidently asserted as representing a general mechanism common across high and low trait-anxious individuals if a dot probe performed alongside had replicated the anxiety-related group differences reported in the literature.

The dot probe has so far not been utilised to shed light upon issues of conscious versus non-conscious processing, nor upon the trajectory of emotion and (connectedly) the impact of emotion regulation at points along this path. Given the strong literature base which has utilised the dot probe methodology, it seems prudent to suggest that future research attempts to bring together those methods with methods from emotion regulation research and newer objective methods for assessing emotional change such as ERPs, eye-movements, skin-conductance or heart-rate measures.

One advantage of these methodologies in comparison to the dot-probe and other button-press tasks is that they do not rely on a motor response. Implicit in the use of button-press tasks in the attention literature is the assumption that emotion only has an effect on attentional processing and not on the decision-making or motor-responding required to complete the task assigned. This assumption is somewhat violated by findings in the embodiment literature that direction of motor response (approach and avoidance) alters reaction times to emotional stimuli according to congruency (e.g. Koch et al., 2008), and it seems possible that even simple forced-choice decisions can be affected by emotion. Consequently, differences in response latencies to emotional stimuli on tasks that require a motor output may reflect effects of emotion in more processes than attention.

6.7 Limitations

Throughout the thesis I have tried to combine cognitive and clinical ideas in a meaningful way but this has inevitably resulted in some compromises and sacrifices. In the attention bias task presented in chapters 2 and 3 I tried to create a task which addressed limitations of the dot probe methodology. However, in asking participants to respond to directly to valenced stimuli it is possible that some response bias was introduced. Measuring eye-movements rather than manual response might circumvent this in the future.

Also in this task, in order to establish location of attention at probe onset, exposure times which allowed conscious access were necessary for the first stimulus in every trial (stimulus exposed until response made). However, having the same exposures for the probe stimuli meant that I was possibly not really tapping into engage and disengage processes as originally intended. I think the best strategy for addressing this limitation would be a slight adjustment of the task such that the second stimulus in each trial was exposed for a fixed duration and not until the participant responses. Additionally, asking participants to perform a dot probe task in addition to the attention bias assessment task would help to understand whether this task truly is measuring something different from the dot probe and how these two behaviours might be related.

The training modification of the attention bias assessment task is something that I wish I had had more time to explore. Two methods for making it more effective might be attempted 1) repeated training sessions over multiple time-points, and 2) training only one move/stay contingency (e.g. disengage and move, engage less and stay). Attention bias modification (ABM) over multiple sessions has become the norm in the literature (e.g. Amir et al., 2009a; Beard & Amir, 2008) although it is unclear how many sessions are necessary for long-lasting clinical impact. As for training only one move/stay contingency, it seems possible that training participants to engage-less and stay as well as engage-less and move is just too complicated and needs to be simplified for effective and non-effortful learning to take place.

The biggest limitation of the continuous flash suppression work presented in chapter four (in the context of this thesis) is that the stimuli used are not actual threat stimuli[58]. Repeating these experiments with fearful or angry faces or with threatening word stimuli would be revealing. Additionally, in testing war veterans I showed that the effect of trustworthiness traits upon preconscious processing which had been shown in students was replicable in an older age-group. However, the two groups of veterans have much in common with each other and testing age-matched non-military controls would allow me to establish what the effect of military training is upon preconscious processing of these traits in faces. Finally, the use of self-report measures is a limitation of these studies. Assessing personality traits through some other means would provide more robust evidence for links between preconscious processes and conscious behaviour.

[58] Although these traits are processed by the amygdala (Said et al., 2009) and are related to threat (Todorov, 2011)

In chapter 5 I sacrificed some of the cognitive psychology rigor in order to utilise paradigms with a greater level of ecological validity which mapped more closely to the concerns reported by patients. However, in doing so I was not able to differentiate between strategic and automatic processes. It would perhaps be fruitful to investigate patterns of eye-movements with the same street scenes when participants are given a specific task to perform (such as memorising scenes or searching for particular items). It would also be interesting to perform an established task like a dot-probe alongside the self-report assessment of hypervigilance and the eye-tracking and look to see if all three are related.

In the head-mounted naturalistic dataset, further analysis is ongoing to extract gaze locations by combining pupil position and participants' view. This will help to establish the kinds of gaze patterns which veterans with and without PTSD are showing and also investigate any connections between these and hypervigilance. At present the discrepancy between the laboratory-based eye-tracking task and the naturalistic task cautions against reliance upon either one alone as indicative of clinically-relevant behaviour.

6.8 Clinical Implications

Patients for whom traditional talking therapies are not effective often describe a disconnect between *knowing* that beliefs and cognitions are irrational or maladaptive but still *feeling* anxious or distressed. Work which endeavours to understand these non-conscious reactions and the links between these and patients' conscious experience is therefore paramount. Attention bias modification paradigms have been propounded as offering great hope in this situation. However, there is much work to be done in order to understand how best these techniques might be applied therapeutically and how long-lasting any effects might be. Understanding how these trained behaviours are similar or different to automatic behaviours in low-anxious individuals would help to indicate the likelihood of long-term change.

Work presented in this thesis points to general mechanisms involved in threat-processing as well as individual differences in processing of non-emotional stimuli. I have shown that targeting biases at more than one stage of processing can increase emotional reactivity to a stressor, and also demonstrated that avoidance can occur at more than one point in attentional processing. Future work which investigates the benefits of encouraging avoidance at different stages would be beneficial; low anxious participants have been reported to show adaptive early avoidance but chapter 4 suggests that pre-attentive suppression is linked to elevated personality traits (of course this may not be the same as psychopathology). Moreover, chapters 2 and 3 suggest that avoidance is employed in both high and low anxious individuals in certain situations; decoupling the hypothesised links between anxiety and avoidance.

6.9 Future work

Throughout the experimental chapters as well as in this final discussion I have tried to indicate where future research might be of interest. Primarily I feel that work which applies cognitive paradigms and concepts to clinical concerns should take priority.

Understanding the role of attentional biases in emotion regulation will require use of paradigms which can separate emotion from emotion regulation. Much of the emotion regulation literature relies on self-reports of ability to regulate emotion; more objective measures are needed. Online measures such as eye-tracking and measures of physiological arousal (e.g. heart-rate, skin conductance or pupil dilation measures) offer potential avenues for investigation. So to do ERP technologies which have excellent temporal resolution and have already yielded potentially interesting results for understanding non-conscious emotional responding (Galli et al., 2011).

In chapter 4 I suggested that fMRI paradigms might be used to investigate further the role of the amygdala and prefrontal cortex in pre-conscious processing of trustworthy and dominant faces. This could be achieved by suppressing faces from awareness using continuous flash suppression and the pre-conscious and post-emergence brain activities could be investigated. Moreover, use of techniques such as tractography or transcranial magnetic stimulation (TMS) would allow insights into functional connectivity between these areas.

Finally, the bidirectional relationship between motor response and emotion could be investigated through use of paradigms which require congruent and incongruent motor response. This style of paradigm has shown potential therapeutic utility for alcoholics (Wiers et al., 2010; 2011) and may offer similar benefits to anxiety patients.

6.10 Final Thoughts

From a review of the cognitive-experimental literature it seemed that establishing which *stage* of attentional processing showed bias in anxious individuals was crucial at this juncture. However, my early work in the thesis suggested that *both* engagement with and disengagement from threat could have an impact upon emotional reactivity, and that there were general mechanisms of attention to threat which cut across individual differences in anxiety traits. Subsequent work on individual differences in personality traits showed that anxiety trait was not alone in biasing pre-conscious processing. Finally, I returned to patient reports of hypervigilance and showed that attentional prioritisation of threat in anxiety is limited as a model for the symptom hypervigilance since not only does it not match descriptions from patients but it also seems that hypervigilance has behavioural correlates even in the *absence of objective threat*.

Throughout my thesis I have kept returning to the concept of avoidance and there appears to be evidence for behaviours which could be described as avoidance at more than one stage of processing. Clearly 'avoidance' needs clearer definition and also further investigation; reaching out to other literature bases for both definitions and methodologies could prove fruitful here. New methodologies employed in this thesis (continuous flash suppression and naturalistic mobile eye-tracking) showed promise for a better understanding of the links between patient experience and observed cognitive-experimental impairments.

This thesis aimed to investigate biased attentional processing of threat in anxiety. Work presented here does not refute the claim that biases in attention are primary in anxiety, however, the evidence suggests that; 1) such biases extend to personality traits other than anxiety, and 2) attentional alterations in anxiety are evident in the absence of objective threat.

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Appendices