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School of Psychology

Visual Attention and Cognitive Biases to Threat in Anxiety

by

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ABSTRACT

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Anxiety disorders are prevalent throughout the lifespan and are associated with a number of negative effects on an individual's quality of life. A large body of research has adopted a cognitive approach to explore factors that are involved in the development and maintenance of elevated anxiety. Cognitive theories of anxiety emphasise the importance of attentional processes and propose that anxiety is characterised by selective attention to threat (e.g., Mogg & Bradley, 1998), impaired attentional control (Eysenck, Derakshan, Santos & Calvo, 2007) and/or hypervigilance and enhanced threat detection (Eysenck, 1992).

This thesis utilised eye movement and reaction time measures to explore the relationship between anxiety and the cognitive mechanisms underlying the localisation and detection of threat. Across four studies the results showed that anxiety was not associated with an enhanced ability to locate threatening stimuli (Experiments 1 and 4). Anxiety was associated with impaired attentional control; individuals with higher levels of anxiety were slower to orient attention towards a task-relevant stimulus in the presence of a threatening distractor (Experiment 2). This effect was apparent even when threatening distractors were presented in peripheral locations, indicating that anxious individuals were able to detect threat within a broad focus of attention. Furthermore, by adopting a broad focus of attention, individuals with higher levels of anxiety were able to integrate threatening information from multiple locations across the visual field; thereby facilitating threat detection in the presence of multiple (vs. single) threats (Experiment 3).

Taken together, the findings indicate that anxiety is characterised by a tendency to maintain a broad focus of attention, where this strategy leads to enhanced threat detection and increased distraction from task-irrelevant threat across the visual field.

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Declaration of Authorship

I, Helen Jane Richards

declare that the thesis entitled

Visual Attention and Cognitive Biases to Threat in Anxiety

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
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Abbreviations

α	Cronbach's alpha
ACS	attentional control scale
ACT	attentional control theory
ADM	affective decision mechanism
ANOVA	analysis of variance
ANT	attentional network task
ATT	attention training technique
β	standardised regression coefficient
b	unstandardised regression coefficient
BVF	both visual fields
CDF	cumulative distribution function
cm	centimetre
d	Cohen's estimate of effect size
df	degrees of freedom
DSM-IV-TR	Diagnostic and statistical manual of mental disorders (fourth edition, text revision)
ERP	event related potential
F	test statistic for ANOVA
fMRI	functional magnetic resonance imaging
FNES	fear of negative evaluation scale
GAD	generalised anxiety disorder
GES	goal engagement system
Hz	hertz
LPP	late positive potential
LVF	left visual field
M	mean
Mdn	median
ms	millisecond
n	sample size
ns	non-significant
OCD	obsessive compulsive disorder
p	probability, significance of a test statistic
PTSD	post-traumatic stress disorder

r	Pearson's product-moment correlation coefficient
r_s	Spearman's rank correlation coefficient
r_w	effect size for the Wilcoxon signed-rank test
R^2	proportion of variance explained by a regression model
RAM	resource allocation mechanism
RDE	remote distractor effect
RT	reaction time
RVF	right visual field
SD	standard deviation
SE	standard error of the mean
SIAS	social interaction anxiety scale
STAI-S	state scale of the state-trait anxiety inventory
STAI-T	trait scale of the state-trait anxiety inventory
t	test statistic for the t-test
T	time
TES	threat evaluation system
VES	valence evaluation system
VIF	variance inflation factor
χ^2	Chi-square test statistic
z	test statistic for the Wilcoxon signed-rank test
°	degree (angle)
2D	two-dimensional
Δ	delta; increment of change

Chapter 1 : Anxiety and Attention

1.1 Anxiety

Anxiety and fear are normal and adaptive emotional experiences that assist individuals in the detection of impending danger and the generation of appropriate behavioural responses (Beck & Clark, 1997). Anxiety and fear are typically associated with a variety of responses that involve cognitive (e.g., worry), behavioural (e.g., avoidance and escape) and physiological (e.g., muscle tension, sweating, heart palpitations) systems (Lang, 1968). Although the symptoms of anxiety and fear converge, the occurrence of these emotional experiences can be distinguished by the immediacy or proximity of the perceived threat; anxiety occurs in response to the possibility or anticipation of a future threat, whereas fear occurs in response to a present danger (Craske et al., 2009).

Anxiety is regarded as atypical when an individual's perception of threat is consistently greater than the objective danger in the environment (Beck & Clark, 1997). The Diagnostic and Statistical Manual of Mental Disorders IV Text Revision (American Psychiatric Association, 2000) lists 12 anxiety disorders including generalised anxiety disorder (GAD), social phobia, posttraumatic stress disorder (PTSD), obsessive compulsive disorder (OCD), and specific phobia. According to DSM-IV-TR, there are a number of symptoms that occur across the anxiety disorders. For example, clinical levels of anxiety are associated with excessive or unreasonable fear and dread, persistent worries and intrusive thoughts, avoidance of the feared object/situation and a variety of physiological symptoms (e.g. palpitations, sweating, nausea, dizziness, shortness of breath, blushing, abdominal distress). In order to meet diagnostic criteria for these anxiety disorders, the symptoms should persist for a minimum duration of time (typically 6 months) and interfere with occupational functioning, social activities and relationships.

Clinical levels of anxiety are typically regarded as an extreme variation on a continuum, rather than as qualitatively distinct from sub-clinical levels of anxiety (Beck & Clark, 1997; Yiend, 2010). For this reason, theories and research in anxiety frequently focus on sub-clinical populations, which include individuals reporting high levels of trait anxiety, state anxiety or social anxiety. It has been argued that elevated trait anxiety is a vulnerability factor in the development of anxiety disorder (Eysenck, 1992). Trait anxiety is regarded as a stable personality dimension that occurs as a consequence of distal factors such as genetics and environmental experiences (Eysenck, 1992; Spielberger, 1985) . In contrast, state anxiety is shaped by proximal factors (e.g., the immediate environment) that occur at the current moment in time (Eysenck, 1992; Spielberger, 1985). Social anxiety can include a fear of interacting or communicating with other people and a fear of public scrutiny (e.g., eating, drinking, speaking) and these are often regarded as two distinguishable forms of social fear (Mattick & Clarke, 1998).

Epidemiological studies have shown lifetime prevalence rates of anxiety disorders in the general population at around 25% (Andrade et al., 2000; Kessler et al., 2005; Kessler et al., 1994). Furthermore, there is evidence to suggest that the prevalence of anxiety disorders in England has increased in the past decade (Mental Health Foundation, 2009). The typical age of onset of anxiety disorders is 11 years (Kessler et al., 2005) and, due to this early onset, there are a multitude of negative outcomes that occur throughout the lifespan. Indeed, a recent meta analysis highlighted the negative impact of anxiety on an individual’s quality of life in relation to five domains: physical health, mental health, social activities, home and family, and work (Olatunji, Cisler, & Tolin, 2007). Specifically, anxiety disorders are linked to prolonged absence from school and work, school drop-out, and fewer qualifications (The National Audit Office, 2005; Van Ameringen, Mancini, & Farvolden, 2003); they are also associated with unemployment, social isolation, reduced social support, relationship problems, marital disruption and a high rate of divorce (Kessler, 2007; Olatunji et al., 2007). These high prevalence rates and negative outcomes highlight the need for research to consider the factors involved in the development and maintenance of elevated anxiety and anxiety disorder.

1.2 Attention

A number of researchers have adopted a cognitive approach in an attempt to understand the factors that underlie elevated anxiety and anxiety disorder (Eysenck, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007; Mogg & Bradley, 1998). It has been proposed that cognition is one of the three components involved in an anxious response (Lang, 1968) and it is likely to be central to the development and maintenance of anxiety for two reasons. Firstly, anxiety is a future-oriented mood state (Barlow, 2002) and the anticipation and worry that occur in response to the possibility of future adverse events will necessarily involve the cognitive system (Eysenck, 1992). Secondly, specific stimuli or situations often provoke anxiety (e.g. spiders, social interactions) and cognitive processes are required to evaluate the affective significance of these stimuli and respond to their potential danger (Eysenck, 1992). In pursuing this cognitive approach, an area that has generated considerable interest is that of pre-attentive and attentional processes in anxiety. Theories and empirical research in this area have tried to elucidate the attentional processes that occur in individuals with high levels of anxiety in the presence of threatening stimuli. This theory and research has, most notably, explored the possibility that anxiety is associated with automatic or pre-attentive processing of threatening stimuli, selective attention to threat and enhanced threat detection. Therefore, before providing a detailed account of the conceptual frameworks of anxiety and attention, it is important to describe: 1) the characteristics of processing, selecting and detecting significant sensory inputs in the environment and; 2) the neural substrates that are likely to underlie selection and detection of emotionally significant stimuli.

1.2.1 Information Processing

Sensory information can be assessed at an automatic or strategic stage of processing. Automatic processes have been defined as those that are involuntary, capacity-free and occur without awareness; strategic processes require conscious attention, cognitive capacity (e.g., resources, effort and energy) and are subject to voluntary control (McNally, 1995). There has been considerable debate regarding the specific temporal relationship between automatic processing and the deployment of attention. It has been agued that, in contrast to pre-attentive processes which always precede attention, automatic processes may also occur after attention has been allocated or may bypass attentional processing entirely (Bargh, 1992). Alternative theories and research suggest that automatic processes are always post-attentive and involve the fast and effortless retrieval of well-practiced memory traces after attention has been deployed on a stimulus (Logan, 1992; Treisman, Vieira, & Hayes, 1992). Importantly, it has been proposed that automatic processes, once initiated, are independent of attention and conscious guidance, irrespective of whether this occurs at a pre-attentive or post-attentive stage of processing (Bargh, 1992; Shiffrin & Schneider, 1977). Information processing, whether automatic or strategic, should provide preliminary information about which objects or locations in the visual field are of potential interest and need to be selected for further processing, *1.2.2 Selection*

In humans there is limited capacity to process all of the available sensory information. Therefore, the cognitive system selects relevant or significant stimuli for further processing and ignores irrelevant stimuli (Hutton, 2008; Luck, 1998). Specifically, it is essential that the cognitive system is capable of selecting high priority signals that are relevant to survival (Dolan & Vuilleumier, 2003). The selection of information from the sensory input can either occur via stimulus-driven processes (e.g., when attention is captured by the abrupt onset of a target) or goal-directed processes (e.g., by voluntarily searching for a pre-specified target (Fan et al., 2009)). Stimulus-driven processes involve the exogenous (bottom-up) capture of attention by properties of the stimulus and goal-directed processes involve the selection of information based on the endogenous (top-down) goals, beliefs and expectations of the observer (Yantis, 1993). Research suggests that the stimulus-driven and goal-directed attentional systems are subserved by distinct anatomical regions in the brain; the stimulus-driven attentional system involves the temporo-parietal and ventral frontal cortex and the goal-directed system involves the prefrontal cortex (Corbetta, Kincade, & Shulman, 2002; Corbetta & Shulman, 2002).

The spotlight metaphor of attention. The size of the attentional window from which sensory information can be selected has been a matter of debate. The spotlight metaphor of attention suggests that a mechanism analogous to a spotlight selects information from one location in the visual field and excludes information from all other locations (Cave & Bichot, 1999; Posner, Snyder, & Davidson, 1980). A small spotlight is particularly important for situations in which it is necessary to select targets for further processing and to simultaneously eliminate distractor interference (Cave & Bichot, 1999). This metaphor suggests that the spotlight is a location-based selection mechanism; that is, attention can only be selectively allocated to a particular stimulus after it has been located (Cave & Bichot, 1999). Furthermore, it has been argued that localisation can only occur after the target stimulus has been discriminated from distractor stimuli (Johnston & Pashler, 1990). Thus, two processes are required before the spotlight of attention can selectively focus on the target: the target must be discriminated from the distractors and then the target must be localised.

Orienting is the mechanism that allows potentially relevant items to be localised and selected for further processing (Fan et al., 2009; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Posner & Petersen, 1990; Posner & Rothbart, 2007; Rueda, Posner, & Rothbart, 2005). The orienting network depends on a reactive posterior attention system (similar to the stimulus-driven attentional system described by Corbetta & Shulman, 2002) that selectively allocates attention to relevant objects/locations in order to enhance perceptual processing in these regions of the visual field (Callejas, Lupianez, Funes, & Tudela, 2005). Orienting involves aligning attention (overtly or covertly) with sensory stimuli in the following sequence: the posterior parietal lobe disengages attention from the current location; the mid brain and superior colliculus shift attention to a new location and; the thalamus and lateral pulvinar engage attention at the new location (Posner & Petersen, 1990).

There are, however, situations in which selective attention disrupts performance in ongoing activities; for example, attention may be captured by and focused on task-irrelevant items via stimulus-driven processes. In these instances, volitional and controlled attentional processes are required to regulate orienting responses (Rueda et al., 2005). It has been suggested that an anterior attention network (similar to the goal-directed attentional system described by Corbetta & Shulman, 2002), located in the frontal cortex, is involved in the effortful control of behaviour and the regulation of the posterior attention network (Rothbart, Derryberry, & Posner, 1994). Brain areas that have been consistently implicated in the functioning of this anterior attention network are the anterior cingulate and lateral prefrontal cortex (Fan et al., 2005; Posner & Rothbart, 2007; Rothbart et al., 1994), which are involved in the modulation of attention, planning, decision making, monitoring competition, motivation, error detection and working memory (Bush, Luu, & Posner, 2000).

The spotlight metaphor of attention assumes that orienting and selection occur via covert attentional processes (i.e. attending to a location without moving the eyes (Posner et al., 1980)). However, there are two reasons to believe that selection is intrinsically linked to overt attentional processes (i.e., moving the eyes). Firstly, visual information is typically sampled and selected in a cognitive visual task by directing the eyes to various locations in the visual field (Liversedge & Findlay, 2000). Indeed, scanning the visual environment with numerous eye movements is a default setting that occurs even when it is not essential or beneficial to the completion of the task (Findlay & Gilchrist, 2003; Zelinsky & Sheinberg, 1997). The necessity of moving the eyes in order to sample and attend to the visual environment can be understood by considering the physiological constraints of the visual system. Specifically, visual acuity declines systematically as retinal eccentricity increases with the fovea, parafovea and periphery corresponding, approximately, to eccentricities of less than 1°, 1-5° and greater than 5°, respectively (Findlay & Gilchrist, 2003). Thus, the constraints of the retinal input to the visual system demand that eye movements operate as a selection mechanism and, in line with the spotlight metaphor of attention, this mechanism depends on the location of objects of interest (Cave & Bichot, 1999). It is necessary to execute eye movements to locations containing objects of interest such that they fall within foveal vision and can be inspected in more detail with high visual acuity (Liversedge & Findlay, 2000). Peripheral vision is used to guide these eye movements by providing information about the nature and location of potential objects of interest (Findlay & Gilchrist, 2003; Findlay & Walker, 1999; Hutton, 2008; Liversedge & Findlay, 2000; Moschovakis & Highstein, 1994).

Secondly, there is a considerable body of theory and research to suggest that there is a close relationship between overt and covert shifts in attention (Hoffman & Subramaniam, 1995; Hutton, 2008; Peterson, Kramer, & Irwin, 2004; Rizzolatti, Riggio, & Sheliga, 1994). In support of this relationship, the pre-motor theory of attention (Rizzolatti et al., 1994) suggests that the preparation of motor actions is responsible for covert shifts in attention and, furthermore, the preparation of oculomotion is particularly important in primates and humans due to the development of foveal vision. This theory predicts that there should be activity in brain regions associated with eye movements during covert shifts of attention (e.g. the superior colliculus). The theory makes two specific predictions: firstly, that executing a saccade to a location in the visual field involves attending to that region and; secondly, that saccades to an attended region will be faster than those to unattended regions. These predictions have been supported by empirical work (Hoffman & Subramaniam, 1995; Peterson et al., 2004). Hoffman and Subramaniam (1995), for example, reported that participants were unable to simultaneously execute a saccade to one location and orient attention to a different location and they concluded that there is an obligatory link between attention and saccades. Furthermore, fMRI data has supported the link between overt and covert attention, indicating that overlapping cortical regions (e.g. the frontal eye fields, supplementary eye fields, parietal and temporal regions) are recruited during covert and overt visual orienting (Corbetta et al., 1998).

The zoom lens metaphor of attention. The zoom lens metaphor of attention extends the spotlight metaphor to suggest that the size of the unitary spotlight can be adjusted in line with task demands such that it increases in size if the exact location of the target stimulus is unknown or is expected within a large region (Cave & Bichot, 1999; Eriksen & St James, 1986; Belopolsky, Zwaan, Theeuwes, & Kramer, 2007). Eriksen and St James (1986) suggested that there would be an even distribution of attentional resources and parallel processing of all stimuli within a wide zoom. However, they also highlighted that there is a limited supply of attentional processing resources; therefore, a broad distribution of attention would be associated with a low density of resources. The rate of processing stimuli and the ability to discriminate fine stimulus details would be reduced given a low density of resources. In contrast, a high density of resources would be deployed on a stimulus given a narrow zoom and this would enhance the rate of processing and the quantity and the quality of the information extracted from the stimulus.

Recent empirical evidence also suggests that the size of the attentional window is under top-down control and can be adjusted flexibly in line with task demands (Belopolsky et al., 2007). Belopolsky et al. (2007) presented three or nine letters in a triangular formation; one letter in each display was a unique colour (red) and the remaining letters were all the same colour (green). In the context of a go/ no-go task, participants were asked to indicate whether a letter E or a letter H were present in the display; target letters were as likely to be the colour singleton as any other letter in the display (note that target colour was task-irrelevant). In the diffuse attention condition, participants were asked to search for and indicate the identity of the target letter when all of the letters in the display formed a triangle that pointed upwards (go condition) and to withhold this response when the display items formed a triangle that pointed downwards (no-go condition). In the focused attention condition, participants were instructed to search for and respond to the target when the fixation point was a circle (go condition) and to withhold this response when it was a square (no-go condition). They found that the search slopes (i.e. the change in reaction time (RT) with an increase in set size) were approximately 27 ms/item in the focused attention condition, irrespective of whether the target was unique (i.e. the colour singleton) or non-unique (i.e., green). In contrast, the search slope was shallower when the target was unique (16 ms/item) compared with non-unique (26 ms/item) in the diffuse attention condition. They concluded that the colour singleton captured attention to a greater extent within a wide (vs. narrow) attentional window. They suggested that while top-down factors (e.g. task instructions) can be used to modulate the size of the attentional window, it is not possible to exert top-down control within the attentional window. Therefore, salient stimuli will capture attention if they are located within the attentional window and this is particularly likely to occur when attention is distributed widely.

These studies are important in highlighting the costs and benefits of maintaining a broad distribution of attention. The costs are that only a low density of processing resources can be allocated to task-relevant stimuli (Eriksen & St James, 1986) and there is a greater chance of attentional capture by task-irrelevant stimuli (Belopolsky et al., 2007) within a broad attentional beam. However, the principal benefit of a broad distribution of attention is that significant stimuli will not go unnoticed even if their exact location or timing is unknown (Eriksen & St James, 1986). Thus, it seems plausible that a broad distribution of attention is particularly beneficial in target detection; that is, if it is known that a target could occur but its location and timing are unknown, then the optimal strategy for target detection would be to monitor and remain hypervigilant within a large area of the visual field (Eysenck, 1992).

1.2.3 Detection

In evolutionary terms, it is essential that the human cognitive system is capable of rapidly detecting high priority signals, especially if they have the potential to threaten survival (Beck & Clark, 1997; Dolan & Vuilleumier, 2003; Mathews, Mackintosh, & Fulcher, 1997). For example, an ability to rapidly detect threat serves as an early warning signal that alerts an individual to danger and, therefore, increases the chances of survival (Beck & Clark, 1997; LeDoux, 1998).

There are a number of processes involved in target detection. Firstly, efficient detection requires that the cognitive system remains in a state of readiness for the possible occurrence of a target. It has been argued that an alerting network sustains activation in the cognitive system over extended periods of time (vigilance) and in response to warning signals (phasic alertness) such that it is possible to respond rapidly to high priority stimuli (Posner & Petersen, 1990). Alerting is associated with activation in diffuse brain locations including frontal and parietal regions of the right hemisphere (Fan et al., 2005).

Signal detection theory highlights that two further important components of target detection are stimulus strength and response bias (Logan, 2004; Tanner & Swets, 1954). A key feature of signal detection theory is that it considers the detection of a signal amongst noise (e.g., a target amongst distractors). Tanner and Swets (1954) suggested that, even in the absence of a target signal, there would be neural activation in response to the background noise in the visual environment. This neural activation would be greater when a target signal was presented amongst the background noise and would continue to increase as the strength of the target signal increased. Tanner and Swets (1954) highlighted that there is also a decisional component involved in target detection; an individual must decide whether the visual array and the associated neural activity are consistent with background noise alone or a target signal amongst background noise. If this decision criterion is low, then minimal neural activity will be required before an individual decides that a target signal is present (i.e., a response bias towards target presence (Logan, 2004)). In contrast, a high level of neural activity will be required to indicate the presence of a target signal if the decision criterion is high (i.e. a response bias towards target absence (Logan, 2004)). It has been argued that psychological and physiological factors can influence the setting of this decision criterion (Tanner & Swets, 1954).

The exact nature of the relationship between target detection and target localisation is unclear. Posner et al., (1980) distinguished between orienting and detecting, suggesting that orienting involves aligning attention with a given stimulus and detection requires that the stimulus has reached a level in the nervous system at which it is possible to make an arbitrary response to signal its presence. On this basis, they argued that orienting to a stimulus is a habitual response that occurs before it is possible to generate a non-habitual (i.e. verbal or manual) response to indicate its presence. Indeed, the spotlight metaphor of attention predicts that target detection is facilitated within the attentional beam, which implies that detection performance depends on the ability to locate the target (Posner et al., 1980). Posner et al (1980) found that there was a benefit in detection latencies to respond to an LED target (i.e., faster responses) when it was presented in a location that had been cued as having the highest probability of containing the target. In contrast, there was a cost in detection latencies (i.e. slower responses) when the LED stimulus was presented in a location that had a low probability of containing the target. They argued that orienting must precede or occur in parallel to detection if it can affect the efficiency of the detection response. Furthermore, they emphasised that this covert orienting response was unrelated to foveal vision and eye movements.

However, Posner et al's (1980) interpretation is likely to be dependent on their definition of detection. As highlighted by the authors, their definition requires an arbitrary and non-habitual response that is almost inevitably slower in comparison with habitual orienting responses. This does not preclude the possibility that there are habitual detection responses (e.g., at the level of neural activation) that precede orienting responses. Indeed, other researchers have either suggested that target detection precedes or can occur in the absence of target localisation (Cave & Wolfe, 1990; Treisman & Gelade, 1980; Treisman & Sato, 1990; Wolfe, 1994; Wolfe, Cave, &

Franzel, 1989) or that detection and localisation occur at a similar stage of processing (Sagi & Julesz, 1985).

1.2.4 The Neural Substrates of Detecting and Selecting Emotional Stimuli

Research has identified the neural substrates that underlie the rapid detection, selection and inhibition of threat and other emotionally significant stimuli (Compton, 2003; Craske et al., 2009; Davis & Whalen, 2001; LeDoux, 1998). This research suggests that emotional stimuli are encoded rapidly and without conscious awareness and that they guide the selection of sensory information from the environment.

It has been argued that a sub-cortical neural circuit including the amygdala and thalamus is involved in the early stages of processing and detecting emotional stimuli based on low-level sensory input (LeDoux, 1998). The amygdala is particularly responsive to negatively valenced stimuli (Davis & Whalen, 2001; LeDoux, 1998). Therefore, it has been proposed that this sub-cortical thalamo-amygdala pathway may serve as a neural substrate for a pre-attentive threat detection mechanism (Dolan & Vuilleumier, 2003) and, furthermore, that anxiety may affect the sensitivity of this mechanism (Mathews & Mackintosh, 1998; Mathews et al., 1997).

Emotionally significant stimuli influence selective attention through a cortical neural circuit including the amygdala and prefrontal cortex. Furthermore, ventromedial regions of the prefrontal cortex, orbital frontal cortex, cingulate cortex and the hippocampus can suppress the inappropriate selection of emotional stimuli (i.e., task-irrelevant stimuli) by exerting top-down control via reciprocal connections with the amygdala. These sub-cortical and cortical pathways are reviewed and described by Compton (2003); Craske et al. (2009); Davis & Whalen (2001), LeDoux (1998).

1.2.5 Summary

This section emphasised that sensory information can be processed at an automatic or strategic level of processing, where automatic processes are those that proceed independently of attention. It also reviewed evidence suggesting that relevant information is selected from the vast array of sensory inputs via stimulus-driven and goal-directed processes, that selective attention depends on a location-based selection mechanism and that it is possible to adjust the size of the selected region. It provided evidence to indicate that the detection of high priority stimuli is enhanced if an individual remains vigilant over an extended period of time, if the strength of the target signal is high and if there is a low threshold for deciding that the target is present.

Finally, this section reviewed evidence to suggest that emotionally significant stimuli are detected via sub-cortical neural circuits and selected via cortical neural circuits.

These features of attention have been of considerable interest in understanding whether a threat processing bias can be regarded as a factor underpinning elevated anxiety. Based on the evidence presented in this section, if threatening information is processed automatically in anxiety, then this will occur involuntarily, without awareness and in a capacity-free manner. However, the validity of using the term ‘automatic’ to refer to cognitive factors in emotion processing has been called into question. Compton (2003) suggested that emotion researchers should be cautious in using this term due to the complexities of defining automatic processes and the methodological difficulties involved in ensuring that stimuli are genuinely perceived without awareness.

Of greater importance in the current work is understanding whether the attentional processes involved in selecting and detecting threat are subject to influence from anxiety. In the context of the preceding discussion on attention, the purpose of selective attention to threat would be to enhance processing of the threatening stimulus and to ignore non-threatening stimuli. This would be accomplished by discriminating between the threats and non-threats in the visual field and by overtly orienting the spotlight of attention to the location containing the threat (i.e. by moving the eyes). Furthermore, a failure to regulate selective attention would be evident in an inability to prevent the spotlight of attention being captured by threat, an inability to disengage the spotlight of attention from threat or an inability to direct the spotlight of attention to a non-threat when threats are present in the visual field. Enhanced threat detection would be accomplished by maintaining vigilance for threat, by amplifying the threat signal or by lowering the threshold for deciding that threat is present in the environment.

1.3 Conceptual Frameworks of Anxiety and Attention

Conceptual frameworks of anxiety and attention have typically considered whether anxiety is associated with: 1) selective attention to threat, where individuals with high levels of anxiety automatically and preferentially select, orient towards and allocate attentional resources to threatening (vs. non threatening) stimuli in their environment (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997); 2) an inability to regulate attention such that individuals with high levels of anxiety fail to inhibit processing of threatening stimuli (Eysenck et al., 2007; Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Lonigan, Vasey, Phillips, & Hazen, 2004); 3) a hypervigilant state which allows anxious individuals to respond rapidly to high priority threatening stimuli (Beck, Emery, & Greenberg, 1985; Beck, Emery, & Greenberg, 2005; Eysenck, 1992; Rapee & Heimberg, 1997).

The majority of the influential conceptual frameworks focus on the relationship between trait anxiety and attention (Eysenck, 1992; Eysenck et al., 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). Eysenck (1992) argued that comparing the cognitive functioning of non-clinical individuals high and low in trait anxiety provides a means of identifying the cognitive factors that predispose those with elevated trait anxiety to anxiety disorder. Moreover, it has been emphasised that similar cognitive processes should be evident in clinically anxious and high trait anxious individuals (Eysenck, 1997). A further point raised by a number of the conceptual frameworks is that the effects of high levels of trait anxiety on attentional processes will be particularly apparent when an individual also experiences high levels of state anxiety (Eysenck, 1992; Eysenck et al., 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997).

1.3.1 Anxiety and Selective Attention to Threat

The majority of the conceptual frameworks of anxiety and attention have focused on the notion that anxiety is characterised by selective attention to threat. These theories propose that individuals with high levels of anxiety allocate attentional resources to threatening stimuli in their environment in preference to neutral or positive stimuli. Therefore, these accounts have similarities with the spotlight metaphor of attention (Posner et al., 1980), where attention is focused on a relevant object or location (i.e., threat) and irrelevant information is ignored (i.e., non-threats). The emphasis placed on selective attention to threat is consistent with the view that orienting and selection are the most important components in the relationship between attention and emotion (Yiend, 2010). These theoretical accounts of selective attention to threat in anxiety can be divided into two subcategories: those assuming that anxiety directly affects selective attention, orienting and the allocation of attentional resources to threat (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Beck & Clark, 1997; Williams et al., 1997) and; those assuming that anxiety affects the initial evaluation of threatening and non-threatening stimuli, where the outcome of this evaluation process is to selectively allocate attention to threat (Bar-Haim et al., 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

Anxiety and the allocation of attentional resources. Williams et al., (1997) proposed that there are two mechanisms involved in stimulus processing: the affective decision mechanism (ADM) and the resource allocation mechanism (RAM). The ADM is proposed to assess the affective valence of a stimulus at a pre-attentive stage of processing and the RAM pre-attentively allocates attentional resources towards or away from a stimulus. Williams et al (1997) suggested that the response tendencies of high and low trait anxious individuals differ at a pre-attentive stage of processing. Specifically, they proposed that trait anxiety affects the functioning of the RAM such that if a stimulus has been labelled as threatening by the ADM, then individuals with high levels of anxiety will allocate attentional resources towards the threat stimulus and individuals with low levels of anxiety will allocate attentional resources away from the threat stimulus. Williams et al (1997) proposed that the tendency to direct resources away from threatening stimuli in low trait anxious individuals represents a protective response as it removes the necessity to process mild threat stimuli and thereby prevents increased anxiety. However, a number of cognitive theorists (e.g., Mathews & Mackintosh, 1998) have highlighted that this account would also suggest that individuals with low levels of anxiety direct resources away from stimuli with a high threat value. If this were the case, then low trait anxious individuals would be unable to implement survival behaviours in objectively dangerous situations. This limitation has been addressed by alternative theories (Mogg & Bradley, 1998).

In a related account, Beck and Clark (1997) suggested that anxiety was associated with an ‘orienting mode’ that was excessively sensitive to threat at the earliest stages of stimulus processing. They proposed that, for all individuals, the function of this orienting system was to identify threatening stimuli (or any stimuli that were important to survival) and to automatically allocate attentional resources to these stimuli such that they received processing priority. They further proposed that a bias in the functioning of the orienting system exists in anxious individuals. Specifically, they suggested that anxiety is associated with enhanced threat detection and, therefore, there is a greater tendency to orient and allocate attentional resources towards threatening stimuli in anxious individuals.

Anxiety and stimulus evaluation. Mogg and Bradley (1998) proposed a two stage model of stimulus processing that consisted of a valence evaluation system (VES) and a goal engagement system (GES). In general, these systems are analogous to the ADM and RAM proposed by Williams et al., (1997). That is, the function of the VES is to automatically assess the affective valence of a stimulus and the function of the GES depends on the inputs it receives from the VES. The GES automatically allocates resources to the stimulus and interrupts current goals if the input it receives suggests that the stimulus is threatening. If a low threat value has been assigned to the stimulus, then the GES continues allocating resources to current goals and inhibits processing of the stimulus. Mogg and Bradley (1998) proposed that the threshold at which the VES labels a stimulus as threatening is lowered in individuals with high levels of trait anxiety and, therefore, the GES directs attentional resources towards threatening stimuli more frequently compared to those with low levels of trait anxiety. Within this framework it is suggested that the VES is not solely influenced by trait anxiety; it is also affected by more objective variables such as the nature of the stimulus and the context in which the stimulus occurs. Hence, a stimulus with an objectively high threat value will be labelled as threatening by the VES in all individuals, irrespective of trait anxiety levels, and will lead to the appropriate allocation of resources by the GES. Therefore, Mogg and Bradley (1998) suggested that vulnerability to anxiety may be reflected in pre-attentive or attentional biases towards mild threat rather than high threat stimuli. An additional component of the model is that, in conjunction with automatic vigilance for danger, high trait anxious individuals may subsequently avoid threat stimuli in order to minimise their discomfort. This pattern of vigilance-avoidance is suggested to maintain anxiety as it precludes habituation to threatening stimuli.

Mathews and Mackintosh (1998) also proposed a model in which trait anxiety had an effect on a threat evaluation system (TES). They argued that an attentional bias to threat could only occur if there was competition between a threatening and non-threatening stimulus. They suggested that anxiety is characterised by the preferential selection of threatening information over non-threatening information, rather than greater speed or efficiency in processing threat. They argued that the output of the TES increases if it automatically assesses and labels the emotional valence of a stimulus as threatening. The output from the TES is also increased in individuals with high levels of trait anxiety. Attentional resources will be directed towards the threat stimulus and directed away from the non-threat stimulus if there is a strong output from the TES. In line with Mogg and Bradley (1998), this model also proposes that objectively high threat stimuli will elicit a strong output from the TES and will lead to orienting to threat in all individuals, irrespective of anxiety. Thus, the effects of anxiety will only be evident when a mild threat stimulus is presented.

1.3.2 Anxiety and Impaired Attentional Control

A number of recent conceptual frameworks have considered the ways in which goal-directed processes can be used to override the bias towards threat and how these processes differ as a function of anxiety (Bar-Haim et al., 2007; Eysenck et al., 2007; Fox et al., 2001; Fox et al., 2002; Lonigan et al., 2004). These frameworks are not necessarily inconsistent with the notion of selective attention and orienting to threat in anxiety; however, they suggest that selective attention to threat is a consequence of impaired attentional control. Attentional control can be defined as the ability to regulate orienting responses through the use of voluntary attention (Derryberry & Reed, 2002) and, therefore, involves using the anterior attentional system to control the deployment of the spotlight of attention (Rothbart et al., 1994; Rueda et al., 2005). Derryberry and Reed (2002) developed a self-report measure of attentional control (Attentional Control Scale; ACS) which aimed to assess the ability to use the anterior attentional system to voluntary focus and shift attention. Whilst some researchers suggest that there is a general deficit in attentional control in anxiety (Eysenck et al., 2007), others suggest that individual differences in attentional control will exist within an anxious population (Derryberry & Reed, 2002; Lonigan et al., 2004). According to the latter view, attentional control can be regarded as a self-regulative trait that moderates the anxiety-related threat bias.

Impaired attentional control. In their Attentional Control Theory (ACT), Eysenck et al (2007) suggested that the balance between the goal-directed attentional system and the stimulus-driven attentional system is disrupted by anxiety. Specifically, anxiety is associated with: automatic processing of threat stimuli due to the increased influence of the stimulus-driven attentional system and impaired attentional control due to the decreased influence of the goal-directed attentional system. Therefore, while previous definitions and measures of attentional control (i.e. ACS; Derryberry & Reed, 2002) focus on voluntary attention and the anterior attentional system, ACT extends these accounts by emphasising the bi-directional relationship between the goal-directed (anterior) attentional system and the stimulus-driven (posterior) attentional system. Eysenck et al., (2007) argued that the impairment in attentional control should lead to negative effects on performance efficiency (i.e. the effort invested to attain a required level of performance on a task) but little or no effect on performance effectiveness (i.e. the accuracy or the quality of task performance). It is important to note that Eysenck et al. (2007) suggested that the impairment in attentional control would occur irrespective of whether a threat-related stimulus was present or absent. In the presence of threat, anxious individuals would automatically allocate attentional resources to task-irrelevant threat, which would lead to a loss of attentional focus and impaired performance on the ongoing task. In the absence of threat, anxious individuals would adopt the optimal strategy for threat detection, which is to maintain a wide distribution of attention and thereby reduce attentional focus on the ongoing task. This latter proposal is consistent with the notion of hypervigilance for threat in anxiety. Eysenck et al (2007) proposed that attentional control is used for inhibition (e.g. inhibiting a prepotent response or resisting distractor interference), attentional shifting (moving between multiple tasks) and updating working memory; and proposed that these functions are impaired in anxiety. It is further suggested that the impairment in these functions should be particularly evident when the anxious individual is presented with threat-related stimuli and when state anxiety is high.

Alternative theories suggest that the processes associated with attentional control (or effortful control) moderate attentional biases to threat-related stimuli (Derryberry & Reed, 2002; Lonigan et al., 2004). According to Lonigan et al (2004), automatic attentional biases mediate the relationship between reactive temperamental processes (e.g. neuroticism) and anxiety. In their model, it is suggested that effortful control processes moderate the risk for increased anxiety by overriding these attentional biases, where effortful control is often defined as a temperamental trait that allows self-regulative behaviour (Rueda et al., 2005). This theory proposes that anxiety will only occur if an individual has high levels of neuroticism in conjunction with low levels of effortful control. An individual who has high levels of neuroticism will be able to regulate their attention to threat and reduce their risk of anxiety if they are able to exert adequate effortful control. High levels of effortful control may, for example, allow an individual with high levels of anxiety to employ compensatory strategies to enhance task performance and decrease attention to threat. These compensatory strategies may include increased effort in tasks requiring inhibition or attentional shifting (Eysenck et al., 2007), thus enabling individuals with high levels of anxiety and high levels of effortful control to inhibit processing of threatening distractors and/or shift attention away from threat.

Delayed disengagement from threat. In contrast to the notion that there is a pervasive impairment in attentional control in anxiety, attention maintenance theory (Fox et al., 2001, 2002) suggests that anxiety is more specifically characterised by slower attentional disengagement from threatening stimuli. This theory proposes that threat stimuli do not influence the initial orienting of attention in anxious individuals.

Instead, the threat bias occurs after the initial orienting of attention due to increased dwell time on threat stimuli. Delayed disengagement can be regarded as a consequence of failing to inhibit the processing of threatening stimuli. This proposal would suggest that the threat-related bias in anxiety can be characterised by post-attentive processes rather than pre-attentive processes.

1.3.3 Anxiety, Hypervigilance and Threat Detection

Eysenck (1992) suggested that trait anxiety is characterised by the rapid detection of threat. He proposed that, in order to enhance threat detection, anxious individuals should be hypervigilant (Eysenck, 1991); they should either rapidly scan the environment with a narrow focus of attention and numerous eye movements or they should maintain a broad focus of attention until a threatening stimulus is encountered. It is argued that this hypervigilant attentional style and broad focus of attention would lead to increased distraction from task-irrelevant stimuli (particularly if it is threatening) in individuals with high levels of anxiety (i.e., impaired attentional control (Eysenck et al., 2007)). Indeed, the ability to focus attentional resources on current tasks would be limited and attentional control would be impaired because a considerable proportion of an anxious individual's cognitive capacity would be dedicated to scanning the environment for threat (Beck et al., 2005).

A further feature of Eysenck's (1992) theory is that, following detection, anxious individuals should selectively attend to threatening (vs. neutral stimuli) such that attention is narrowed onto the threat stimulus in order for it to be processed in more detail (as indexed by more fixations on these stimuli). This suggestion is consistent with the zoom lens metaphor of attention (Eriksen & St James, 1986), where the size of the attentional spotlight expands if the location of the target stimulus is unknown and contracts if the location of the target stimulus is known.

In addition to high trait anxiety, the notion of hypervigilance has also been raised in models of social phobia (Beck et al., 2005; Rapee & Heimberg, 1997). Rapee and Heimberg (1997) suggested that, after detecting an audience, individuals with social phobia are hypervigilant for external sources of threat in the form of signs of negative evaluation (e.g. frowns), anger and aggression.

1.3.4 Summary of the Current Conceptual Frameworks

The most consistent feature across the cognitive models of anxiety is the assumption that anxious individuals automatically select threatening information for further processing at the expense of processing non-threatening stimuli or carrying out ongoing tasks. This anxiety-related bias may manifest itself in a variety of forms; the automatic allocation of attentional resources to threat (Beck & Clark, 1997; Williams et al., 1997), a lowered threshold for evaluating a stimulus as threatening (Mogg & Bradley, 1998), an amplification of the threat signal (Mathews & Mackintosh, 1998), or an inability to inhibit threat processing or disengage from threat stimuli (Eysenck et al., 2007; Fox et al., 2001, 2002). The notion of hypervigilance (Beck et al., 2005; Eysenck, 1992) adds a further dimension to these theories. Although Eysenck (1992) suggests that there is a selective attentional bias and a narrowing of attention onto threat in anxiety, he also highlights that the initial phase of threat detection may be enhanced by distributing attentional resources widely and scanning the environment for threat.

Chapter 2 will review the empirical evidence that has been conducted to test the predictions put forward by these conceptual frameworks of anxiety and attention. It will discuss the progress that has been made in understanding threat processing in anxiety and it will also highlight some of the important questions that remain in this field of research. Finally, Chapter 2 will outline the approach that is used in this thesis to address these research questions. Specifically, it is argued that a greater understanding of anxiety and attention requires a more comprehensive amalgamation of the principles, theories and findings underlying research in the separate fields of cognition and emotion. A more thorough consideration of the purpose and mechanisms involved in attentional selection and target detection should provide greater insight into whether these processes are affected by emotionally significant stimuli in anxiety.

Chapter 2 : An Empirical Review of Threat Processing in Anxiety

2.1 Introduction

Empirical research on anxiety and attention has utilised a variety of cognitive paradigms and experimental techniques to elucidate the attentional processes underlying the anxiety-related threat bias. Behavioural (RTs), neuropsychological (eye movements), electrophysiological (event related potentials; ERPs) and neuroimaging (functional magnetic resonance imaging, fMRI) measures have, most notably, provided evidence of selective attention to threat (Bradley, Mogg, Falla, & Hamilton, 1998; Garner, Mogg, & Bradley, 2006; Mueller et al., 2009), impaired attentional control (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Mogg et al., 2000; MacNamara & Hajcak, 2010) and enhanced threat detection (Byrne & Eysenck, 1995; Matsumoto, 2010) in anxiety. Presently, there is only a small literature on hypervigilance and the breadth of attention in anxious individuals (Horley, Williams, Gonsalvez, & Gordon, 2004; Keogh & French, 1999; Shapiro & Lim, 1989). This chapter will review the existing literature on attentional processing of threatening stimuli in anxiety; it will highlight that, from a cognitive perspective, there are a number of unresolved issues surrounding the processes and mechanisms involved in the selection, inhibition and detection of threat and; it will outline the approach adopted in this thesis to explore these issues.

Before providing a detailed review of the existing literature on anxiety and attention, it is important to outline the participant characteristics and stimulus considerations that frequently underlie this work. As highlighted in Chapter 1, empirical research on threat processing in anxiety has been conducted with clinically anxious individuals and sub-clinical populations with high levels of self-reported anxiety. In their meta-analysis, Bar-Haim et al (2007) reported that there was no difference between these groups in the effect size of the threat bias. Furthermore, they found that this effect size was similar across clinical anxiety disorders and that it was equivalent in adult and child populations. These findings suggest that it is of theoretical value to consider the threat bias in all individuals with high levels of anxiety, irrespective of their age and the clinical status of their anxious symptomatology.

The nature of the threatening stimuli used in these studies has developed over time, with earlier studies focusing on threatening word stimuli and more recent studies often employing threatening pictures. It has been argued that threatening word stimuli are more abstract and less salient than pictorial threat cues (Bradley, Mogg, & Millar, 2000). Furthermore, it has been suggested that an anxiety-related attentional bias to threatening words may be confounded by word familiarity because individuals with high levels of anxiety (vs. individuals with low levels of anxiety) display heightened familiarity with these stimuli (Bradley et al., 2000; Calvo & Eysenck, 2008). Recent research has increasingly favoured the use of more naturalistic threat stimuli such as emotional faces. Indeed, the empirical work presented in this thesis utilises threatening and non-threatening facial expressions. Faces are widely regarded as important stimuli, perceived using specialised neural regions in the human brain (Kanwisher & Yovel, 2006). Emotional facial expressions are encountered from birth and are considered to be meaningful stimuli in the development of normal social interaction (Herba & Phillips, 2004). Given the significance of faces, it is of interest to consider whether threatening facial expressions receive processing priority in anxious individuals. Angry faces, for example, denote dominance and aggression and are associated with survival threats in mammalian evolutionary history (Mineka & Öhman, 2002) and, as such, are likely to be perceived as particularly threatening by those who are anxious or fear social interactions.

2.2 Anxiety and Selective Attention to Threat: Empirical Evidence

Cognitive models of selective attention to threat suggest that individuals with high levels of anxiety allocate processing resources towards rather than away from threat (Beck & Clark, 1997; Williams et al., 1997) and that they have a lowered threshold for evaluating a stimulus as threatening (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). With respect to the allocation of attentional resources, empirical research has typically considered the following questions: Do anxious individuals preferentially attend to threatening (vs. neutral) stimuli? Is anxiety characterised by rapid orienting towards threat at an early stage of stimulus processing? With respect to stimulus evaluation, the principal question of interest is whether anxious individuals are more inclined to interpret ambiguous stimuli as threatening.

2.2.1 The Allocation of Attentional Resources

Evidence to support the proposition that individuals with high levels of anxiety selectively allocate attentional resources to threatening stimuli in preference to neutral stimuli has typically been found using an emotional variant of the dot probe paradigm

(Bar-Haim et al., 2007; Yiend, 2010). This paradigm involves the presentation of stimulus pairs, which consist of an emotional stimulus (threatening or positive) and a neutral stimulus displayed simultaneously to the left and right of central fixation. The stimulus pair is replaced by a dot probe, which either appears in the location of the previous emotional stimulus or the location of the previous neutral stimulus. The task is to make a decision about the presence/absence, location or identity of the probe. The rationale underlying the task is that if an individual selectively orients their attention towards one of the items in the stimulus pair, then RTs to the subsequent dot probe will be faster if the probe appears in the same location as the ‘selected’ stimulus compared with the same location as the ‘unselected’ stimulus. Indeed, if the subsequent dot probe appears in the same location as the selected stimulus, then the individual can process and respond to the probe without shifting their attention between spatial locations. If a subsequent dot probe appears in the same location as the unselected stimulus, then the individual will need to disengage their attention from the selected location and shift their attention to the unselected location before they can process and respond to the probe.

It has been argued that vigilance for threat would be reflected in RTs that are faster when the probe replaces the threat stimulus compared with when the probe replaces the neutral stimulus. In contrast, threat avoidance would be associated with RTs that are slower when the probe replaces the threat stimulus compared with when the probe replaces the neutral stimulus (MacLeod, Mathews, & Tata, 1986). It is important to note that the term ‘vigilance’ tends to be used interchangeably with ‘selective attention’ in the dot probe literature. In this context, vigilance refers to only one subsection of Eysenck’s (1991, 1992) hypervigilance theory. Specifically, the term is used to indicate that, following threat detection, anxious individuals selectively process and narrow their attention onto threatening stimuli.

The dot probe paradigm has generated a body of highly replicable findings using various stimuli (e.g. faces, words, spiders) in sub-clinical and clinical populations. A number of studies indicate that individuals with high levels of anxiety selectively attend to threatening stimuli (i.e. where probe responses are faster when the probe replaces the threatening compared with the neutral stimulus). These findings of selective attention to threat have been demonstrated with high trait anxious individuals (Bradley et al., 1998), high state anxious individuals (Mogg, Bradley, DeBono, & Painter, 1997), individuals with a clinical diagnosis of GAD (MacLeod et al., 1986), individuals with a clinical diagnosis of social phobia (Mogg, Philippot, & Bradley, 2004) and spider fearful individuals (Mogg & Bradley, 2006). These studies typically indicate that the threat bias does not occur in non-anxious control participants and that there is not a bias for happy faces in individuals with high levels of anxiety. However, with respect to the latter point, there is some limited evidence from the dot probe paradigm to indicate that anxious individuals are vigilant for angry and happy faces (Bradley, Mogg, White, Groom, & DeBono, 1999). Explanations for this type of emotional bias (i.e. the preferential allocation of attentional resources to happy and angry faces) typically suggest that individuals with high levels of anxiety interpret both happy and angry faces as threatening; specifically, it is possible that they evaluate a happy face as a sign of being mocked (Bradley et al., 1999; Garner et al., 2006).

Dot probe findings of selective attention to threat in anxiety are reliably observed when the stimulus pairs are presented for a short duration (i.e. up to 500 ms (Bradley et al., 1998; Mogg & Bradley, 2006; Mogg et al., 1997; Mogg et al., 2004)) and they are less reliable when the stimulus pairs are presented for longer durations (i.e., over 1250 ms (Bradley et al., 1998; Mogg & Bradley, 2006; Mogg et al., 2004)). This evidence has been interpreted as suggesting that selective attention and vigilance for threat occurs at an early stage of stimulus processing in anxious individuals (Mogg & Bradley, 2006). Additional studies have found that the threat bias occurs even when the threat stimuli are presented subliminally under conditions that preclude conscious processing (Bar-Haim et al., 2007; Mogg & Bradley, 1999; Mogg & Bradley, 2002). These findings are consistent with the notion of a pre-attentive threat bias in anxiety.

Yiend (2010) recently highlighted the strengths and limitations of the RT dot probe paradigm. She argued that a benefit of the paradigm is that it provides convincing evidence to indicate that anxious individuals selectively allocate attention to threatening stimuli in preference to neutral stimuli. However, a limitation associated with the dot probe paradigm is that it can only consider the attentional bias to threat at the snapshot of time in which the probe occurs and, therefore, it is not possible to infer whether attention was also allocated to the threatening stimulus before or after the onset of the probe. She argued that a further limitation is that this paradigm cannot readily be used to distinguish between initial orienting to threat and delayed disengagement from threat. Recently, eye movement and ERP measures have been utilised to address these limitations; these measures allow a consideration of the spatial and temporal characteristics of orienting attention from the onset until the offset of the threatening stimulus.

There are currently relatively few studies that have considered selective attention to threat by measuring the eye movement behaviour of anxious individuals during threat processing. Several studies (Garner et al., 2006; Mogg, Garner, & Bradley, 2007; Mogg, Millar, & Bradley, 2000) have utilised traditional RT dot probe tasks and concurrently measured eye movements in individuals with high levels of anxiety when they are presented with picture pairs containing one emotional picture and one neutral picture. These studies indicate that, in comparison with non-anxious control participants, there is initial vigilance for: angry faces in individuals with GAD (Mogg et al., 2000); angry and fearful faces in individuals with high trait anxiety (Mogg et al., 2007) and; angry and happy faces in individuals with high fear of negative evaluation when experiencing current social-evaluative stress (Garner, et al., 2006; note that a vigilant-avoidant pattern of eye movements was observed in this study). Heightened vigilance in these studies was inferred from a higher proportion of first fixations or initial saccades landing on the emotional face (vs. the neutral face), shorter latencies between the onset of a stimulus pair and the first fixation on emotional faces (vs. neutral faces), and shorter latencies between the onset of a stimulus pair and the initial saccades to emotional faces (vs. neutral faces). The conclusion drawn from these studies is that there is a bias in initial orienting to threat in anxiety (Mogg et al., 2000). These studies support the proposition that individuals with high levels of anxiety selectively attend to threat.

Findings of initial vigilance for threat have not always been replicated in eye movement studies (Gerdes, Pauli, & Alpers, 2009). Gerdes et al. (2009) found that high and low spider fearful individuals did not differ in the latency between the onset of a display and the first accurate fixation when participants were instructed to look towards a spider picture (paired with a neutral picture). However, when instructed to move their eyes away from the spider picture, the latency between the onset of a display and the first accurate fixation was longer in high fearful individuals compared with low fearful individuals. They concluded that high fear was not associated with the rapid allocation of attention towards threat; instead, it was characterised by slowed disengagement from threat (see Section 2.3.2 for further evidence of delayed disengagement from threat in anxiety).

To consider vigilance, disengagement and avoidance in further detail, additional eye tracking studies have considered the temporal characteristics of the threat bias in anxiety by presenting stimuli for 2000 – 9000 ms. Studies that have used emotional-neutral picture pairs and allowed free viewing have found evidence of initial vigilance for angry and happy faces in individuals with a heightened fear of negative evaluation

(Wieser, Pauli, Weyers, Alpers, & Muhlberger, 2009) and social phobia (Gamble & Rapee, 2010) and initial vigilance for positive and threatening pictures in individuals with high levels of trait anxiety (Calvo & Avero, 2005). In these studies, vigilance was inferred from a higher probability of first fixations, or a higher proportion of total fixations or total viewing time directed towards the emotional (vs. neutral face) within the first 500 ms or 1000 ms of stimulus presentation.

However, further studies using a similar methodology have found no evidence of anxiety-related vigilance for threat at early stages of viewing; instead, they have found evidence of avoidance of threat from 500 ms of viewing time onwards (Hermans, Vansteenwegen, & Eelen, 1999; Pflugshaupt et al., 2007; Rohner, 2002). For example, Rohner (2002) monitored the direction of gaze during presentation of angry-neutral and happy-neutral face pairs and reported that gaze was averted from angry faces to a greater extent than happy faces in high trait anxious individuals (but not low trait anxious individuals) from 1800 ms onwards. Similarly, Pflugshaupt et al., (2007) presented participants with picture pairs containing a spider and a non-spider (e.g. a butterfly) for 9 seconds. They found that there was a significantly shorter viewing time and a lower percentage of fixations on spiders in the spider phobic group compared with the control group. Furthermore, they found evidence of gradual oculomotor avoidance in the spider phobic group, where the percentage of fixations on the spider picture decreased over time. See further eye tracking evidence for avoidance of spiders in spider anxious individuals in Hermans, et al., 1999 and avoidance of emotional scenes in high trait anxious individuals in Calvo & Avero, 2005.

Thus far, eye tracking studies have been unable to definitively determine whether selective attention to threat in anxiety is a consequence of rapid orienting towards threat or delayed disengagement from threat or whether anxiety is more consistently characterised by a tendency to avoid threat. The inconsistencies between these eye tracking findings may be a result of differences between the anxiety groups and differences in the task instructions. For example, the findings indicate that individuals with high social anxiety are vigilant for emotional faces in general (Gamble & Rapee, 2010; Garner et al., 2006), whereas individuals with GAD or high trait anxiety are more likely to demonstrate threat-specific vigilance (Mogg et al., 2007; Mogg et al., 2000). On the other hand, fear of spiders is typically associated with slow and controlled processes such that there is evidence of delayed disengagement (Gerdes et al., 2009) or attentional avoidance (Pflugshaupt et al., 2007) from threat.

Further evidence of selective attention to threat has been provided in ERP studies (Eldar, Yankelevitch, Lamy, & Bar-Haim, 2010; Fox, Derakshan, & Shoker, 2008; Mueller et al., 2009). Mueller et al., (2009), for example, measured the P1 component (measured at 80-150 ms post-stimulus onset) as an index of rapid orienting of covert spatial attention during a dot probe task in which angry-neutral or happy-neutral face pairs preceded the dot probe. They found that the P1 amplitude was greater in response to the angry-neutral face pairs compared with the happy-neutral face pairs in individuals with social anxiety disorder (this effect was not observed for control participants). This finding was consistent with the behavioural RT data in which individuals with social anxiety disorder, but not the control participants, were faster to respond to probes that replaced angry compared with happy faces. They concluded that these findings were indicative of hypervigilance and rapid spatial orienting to threat in anxiety.

Similarly, Fox et al., (2008) and Eldar et al. (2010) presented angry-neutral or happy-neutral face pairs and asked participants to manually respond to a subsequent target. Fox et al., (2008) measured ERPs in response to the face pairs and found that there was a rapid shift of attentional resources towards threat (i.e. angry faces) in high trait anxious individuals as indexed by an enhanced N2pc component (this was not evident in low trait anxious individuals or for happy faces). In contrast, Eldar et al (2010) reported that the amplitude of the C1 component (65-105 ms post-stimulus onset) was greater in individuals with high (vs. low) levels of trait anxiety in response to angry-neutral (but not happy-neutral) face pairs. They concluded that anxiety was associated with a more intense response to threat.

Taken together, these ERP studies provide preliminary electrophysiological evidence to indicate that anxious individuals orient covert attention to threatening stimuli in preference to neutral stimuli at early stages of processing. However, these results need to be treated with caution because the ERP literature on attentional biases in anxiety currently uses a wide variety of experimental tasks and focuses on different ERP components. Even studies using similar tasks, such as those presented above, identify different ERP components to explain a single phenomenon. Thus far, there are an insufficient number of studies to determine whether these are replicable effects.

To summarise, the studies reviewed in this section have been of central importance in providing converging evidence from RTs, eye movements and ERPs to indicate that individuals with high levels of anxiety allocate attentional resources to threatening stimuli in preference to neutral stimuli. It is argued here that, in contrast to the conclusions that are typically drawn from these studies, this attentional bias does not necessarily imply that there is selective attention to threat in anxiety. To refer back to Chapter 1, the evolutionary purpose of selective attention is to ensure that the limited capacity cognitive system selects high priority signals for further processing from a large array of competing environmental stimuli. Therefore, it is important to determine whether anxiety is associated with an enhanced ability, rather than just a preference, to select high priority threat signals from competing visual inputs. Selectively attending to a particular stimulus requires that the spotlight of attention is directed to its location and, therefore, an important line of enquiry is to establish whether anxiety is associated with enhanced threat localisation. Furthermore, it is important to determine the parameters of selective attention to threat; that is, a selective attentional mechanism is of limited value if it only operates when two items are present in the visual field. If selective attention to threat is a fundamental attribute in anxious individuals, then it should be evident regardless of the complexity (i.e., the number of items) in the visual environment.

2.2.2 Stimulus Evaluation

It is possible that the preference to allocate attentional resources to threat in anxiety is the result of a lowered threshold for evaluating a stimulus as threatening (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Although the significance of research on anxiety and stimulus evaluation is acknowledged (i.e., the interpretative bias), only a very brief summary of this research will be provided here because this thesis is primarily concerned with the relationship between anxiety and the deployment of attention.

The literature on anxiety and stimulus evaluation has typically considered the notion that anxious individuals evaluate or interpret ambiguous stimuli as threatening (Blanchette & Richards, 2010). The interpretative bias has principally been assessed using two methodologies. Firstly, many studies present participants with words, sentences or situations that are ambiguous and, therefore, could have a threatening or a neutral meaning. These studies frequently find that clinically anxious individuals and individuals high in trait or social anxiety are more likely to generate the threatening (vs. neutral) interpretation of ambiguous stimuli (Blanchette & Richards, 2010; Mathews, Richards, & Eysenck, 1989). Mathews et al. (1989), for example, asked participants to listen to a list of words and to write down each word after they heard it. The word list included unambiguously threatening words (e.g., ‘hazard’), unambiguously neutral words (e.g., 'blanket') and homophones. The homophones were words that had two meanings (threatening and non-threatening) and two spellings but the same pronunciation (e.g., 'die/dye', 'groan/grown', 'weak/week'). They found that all participants generated the threatening spelling of the homophone more frequently compared with the neutral spelling. Furthermore, the percentage of homophones that were spelled in the threatening form was greater in individuals with GAD (85%) compared with the control participants (70%). They concluded that anxious individuals were inclined to interpret ambiguous stimuli as threatening and that this may serve to cause or maintain anxiety.

Secondly, a number of studies have created ambiguous emotional faces by morphing two facial expressions. These studies have found that anxious individuals demonstrate enhanced identification and sensitivity to anger and fear in ambiguous facial expressions (Blanchette & Richards, 2010; Richards et al., 2002). Richards et al., (2002), for example, morphed faces along six continua: happiness-surprise, surprise-fear, fear-sadness, sadness-disgust, disgust-anger, anger-happiness. Within each continuum, every morphed face was created by blending prototypical emotions in varying proportions. On the anger-happiness continuum, for example, the angry prototype (100% anger) and happy prototype (100% happiness) were blended to create morphed faces with the following proportions of anger and happiness: 90%: 10% (e.g., mainly angry), 70%:30%, 50%:50%, 30%:70%, 10%:90% (e.g., mainly happy). Participants were asked to classify the emotion expressed in each morphed face in a forced choice response task; that is, they had to classify the face as happy, surprised, fearful, sad, disgusted or angry. Richards et al (2002) primarily considered the number of fear classifications made on the surprise-fear and fear-sadness continua, the number of angry classifications made on the disgust-anger and anger-happiness continua, and the number of happy classifications made on the happiness-surprise and anger-happiness continua. They found no evidence to suggest that angry or happy classification responses were influenced by social anxiety. However, they did find that high socially anxious participants classified more of the faces on the fear continua as expressing fear compared with the low socially anxious participants. They concluded that there was an interpretative bias in anxiety such that ambiguous facial expressions were more likely to be interpreted as expressing fear in individuals with high social anxiety. They argued that this interpretative bias was consistent with the notion that individuals with high levels of anxiety are hypervigilant for signals of danger.

2.2.3 Summary

The existing literature on selective attention to threat provides evidence to suggest that anxiety is associated with a bias in allocating attentional resources to threatening stimuli in preference to neutral stimuli and a tendency to evaluate ambiguous stimuli as threatening. These findings provide some evidence of selective attention to threat in anxiety; however, further work is required to consider how anxiety affects the mechanisms that underlie attentional selection (i.e., localisation) and the parameters in which they operate (e.g., the ability to localise threat as the number of stimuli or the complexity in the visual environment increases). With respect to threat localisation, it is possible that selective attention to threat in anxiety will manifest itself as rapid orienting towards and/or delayed disengagement from the location of the threatening stimulus. This may occur as a consequence of an enhanced ability to generate orienting responses towards threatening stimuli or a difficulty regulating orienting responses in the presence of threatening stimuli. The latter proposition would be consistent with existing empirical research highlighting that there is impaired attentional control in anxiety.

2.3 Anxiety and Impaired Attentional Control: Empirical Evidence

In considering the role of impaired attentional control in anxiety, empirical evidence has typically focused on whether individuals with high levels of anxiety are able to inhibit processing of threatening stimuli. According to ACT (Eysenck et al., 2007), anxiety should be characterised by impairments in inhibitory processes in the presence and, to a lesser extent, in the absence of threatening stimuli. ACT also highlights that impaired attentional control will lead to deficits in shifting attention between multiple tasks and updating working memory; however, these functions are not as clearly related to the aspects of attention that are considered in this thesis (e.g. selection and detection) and, therefore, will not be discussed in further detail. Fox and colleagues (2001, 2002) proposed that there is a more specific impairment in attentional control in anxiety in which there is a delay in disengaging attention from threatening stimuli.

2.3.1 Impaired Attentional Control

Findings from the emotional Stroop paradigm have provided evidence that anxiety is associated with difficulties in inhibiting the processing of threatening stimuli

(Bar-Haim et al., 2007; Williams, Mathews, & Macleod, 1996; Yiend, 2010). In the original Stroop paradigm (Stroop, 1935), participants were asked to name the colour a word was written in and ignore the semantic content of the word. It was argued that interference from the semantic content of the word was reflected in longer response latencies to name the colour of the word. In the emotional version of this task, emotional words or faces are presented in various font colours and the participant is asked to colour name the stimulus as quickly as possible while ignoring (i.e. inhibiting) the affective content of the word or face. A number of studies have found that anxious individuals are slower to colour name threatening stimuli compared with neutral stimuli, indicating that they are unable to inhibit threat processing. Specifically, greater interference from threatening (vs. neutral) stimuli has been reported in clinically anxious individuals (Mathews & MacLeod, 1985; Mathews, Mogg, Kentish, & Eysenck, 1995; Mogg, Mathews, & Weinman, 1989), high trait anxious individuals (Mogg et al., 2000) and individuals with elevated levels of both state and trait anxiety (MacLeod & Rutherford, 1992; Rutherford, MacLeod, & Campbell, 2004). Although some research suggests that Stroop interference from threatening stimuli occurs at a pre-attentive stage of processing in anxious individuals (MacLeod & Rutherford, 1992; Wikström, Lundh, & Westerlund, 2003), others suggest that it is driven by a slow and controlled process involving disengagement from threat (Bar-Haim et al., 2007; Phaf & Kan, 2007). Findings from these studies also indicate that the threat bias does not occur in non-anxious control participants and that there is typically no bias for happy faces in anxious individuals. With respect to the latter point however, there are examples of studies in which the magnitude of Stroop interference was equivalent for positive and negative stimuli in anxious individuals (Martin, Williams, & Clark, 1991; Reinholdt-Dunne, Mogg, & Bradley, 2009).

Findings of Stroop interference from threat stimuli in anxious individuals are frequently interpreted as evidence of vigilance and a selective attentional bias to threat (Bar-Haim et al., 2007). However, it has been suggested that this paradigm is not an ideal method for testing selective attention because the relevant (colour) and irrelevant (semantic content) components of the task are presented in the same spatial location (Fox, 1993). The spotlight metaphor of attention suggests that selection occurs through the use of a location-based mechanism (Cave & Bichot, 1999); therefore, if task-relevant and task-irrelevant dimensions occupy the same location, then both dimensions are likely to be selected for further processing. However, further RT (Fox, 1993; Fox, 1994; Fox, 1996; Georgiou et al., 2005) and eye tracking studies (Derakshan et al., 2009; Wieser, Pauli, & Muhlberger, 2009) have extended the Stroop paradigm to consider the ability to inhibit threat that appears in a different location to the task-relevant stimulus.

Using experiments in which relevant and irrelevant components of a task were presented in different spatial locations, Fox and colleagues found that there was only evidence of a selective attentional bias to threat in anxiety when the task-irrelevant threat stimuli were presented within focal attention (i.e. within foveal vision). For example, Georgiou et al., (2005) presented task-irrelevant fearful, happy or neutral faces in the centre of the screen and asked participants to categorise letters presented in the periphery while keeping their eyes focused on the central face. Their results indicated that participants with high levels of trait anxiety were slower to categorise the letters when the face was fearful compared with non-fearful (happy or neutral). This effect was not observed in participants with low levels of trait anxiety. Similarly, Fox (1996) reported that threatening (vs. neutral) distractor words delayed RTs to categorise a target stimulus in high trait anxious individuals if they were presented within foveal vision. These findings suggest that high trait anxiety is associated with selective attention to threatening distractors presented within focal attention (in this case a delay in disengaging from or inhibiting threat stimuli). In contrast, Fox (1993, 1994) used a separated Stroop task in which a central colour patch was flanked by threatening, neutral or colour words presented outside focal attention. The results indicated that, in high trait anxious individuals, there was either no evidence of slowed colour naming of the patch in the presence of threat words (vs. neutral words; Fox, 1994) or that there was a general difficulty inhibiting distracting stimuli, where colour naming the patch was slower in the presence of threatening and colour words compared with neutral words (Fox, 1993). These studies extend the Stroop paradigm to indicate that the failure to inhibit threat processing is not limited to situations in which the task-relevant and task-irrelevant stimulus dimensions are presented in the same spatial location.

Similarly, in recent eye tracking studies participants were asked to inhibit processing of a threatening (or non-threatening) stimulus in order to execute a saccade to a different location. Specifically, the antisaccade paradigm has been used to explore the possibility that anxiety is associated with impaired inhibition of threatening stimuli (Derakshan et al., 2009; Wieser et al., 2009). In this task, participants are presented with a peripheral visual cue; in the prosaccade condition they are asked to look towards the cue as quickly as possible and in the antisaccade condition they are asked to look away from the cue as quickly as possible. Accurate performance in the antisaccade condition requires the inhibition of an exogenous prosaccade to the cue and volitional programming of an endogenous antisaccade to the mirror position. Therefore, a typical finding in this paradigm is that accurate first saccade latencies are slower in the antisaccade condition compared with the prosaccade condition. In Experiment 2, Derakshan et al., (2009) presented participants with face cues (angry, happy or neutral) in peripheral locations and asked participants to either execute a saccade towards the cue in the prosaccade condition or away from the cue in the antisaccade condition. Participants were also instructed to make a manual keypress response to indicate the direction of an arrow that appeared immediately following the cue; this arrow appeared in the same location as the cue on the prosaccade task and in the opposite location to the cue in the antisaccade task. Derakshan et al., (2009) reported that the latency of the accurate first saccades in the antisaccade condition were significantly longer in the high trait anxious group compared with the low trait anxious group when the cue was an angry face. This effect was not observed for neutral or happy cues in the antisaccade task or for any cue in the prosaccade task. Furthermore, there was no effect of anxiety on the error rate in the antisaccade task (e.g. where the participant incorrectly executes a prosaccade to the cue). They concluded that there was an impairment in inhibiting processing of threatening stimuli in anxious individuals.

However, contrasting findings were reported by Wieser et al., (2009) in a similar antisaccade task which included angry, happy, fearful, sad and neutral faces as cues. Here, the study found that individuals high in fear of negative evaluation made significantly more errors (i.e. prosaccades to the cue) in the antisaccade task compared with control participants for all facial expressions. They did not find any evidence to indicate that anxiety affected the latency of the first saccade on the antisaccade task. They concluded that there was a general attentional control deficit in anxious individuals (i.e. it was not threat specific). Taken together, these two studies concur in highlighting that anxiety is associated with impaired attentional control and, furthermore, there is some evidence to indicate that this impairment is associated with a specific difficulty in inhibiting threat processing (Derakshan et al., 2009).

The RT studies conducted by Fox and colleagues (Fox, 1993, 1994, 1996; Georgiou et al., 2005) and the antisaccade studies (Derakshan et al., 2009; Wieser et al., 2009) have provided important evidence to indicate that anxiety is associated with an impairment in attentional control. However, the findings cannot fully address the proposition raised in ACT (Eysenck et al., 2007) that there is an imbalance between the stimulus-driven and goal-directed attentional systems in anxiety. Firstly, a limitation of

Fox et al's studies is that participants were instructed to maintain central fixation either on a threatening distractor (Georgiou et al., 2005) or on the task-relevant neutral targets (a colour patch or a numerical digit; Fox, 1993, 1994, 1996). This task requirement does not allow stimulus-driven and goal-directed processes to be placed in direct competition; the former case favours processing of the task-irrelevant stimulus and the latter case favours processing of the task-relevant stimulus. Secondly, while the antisaccade studies are indicative of an impairment in goal-directed processes and/or increased influence of stimulus-driven processes in the presence of threat in anxiety, it is unclear whether this effect on eye movement behaviour also occurs when a task-relevant stimulus competes for attention with task-irrelevant threat.

Some authors have argued that to fully assess the balance between the stimulus-driven and goal-directed attentional systems, it is necessary to consider whether attention is captured by a stimulus when it is task-irrelevant and is presented in competition with a task-relevant stimulus (Van der Stigchel et al., 2009). In this case, it becomes possible to establish whether the stimulus is selected for further processing via an involuntary (exogenous) shift in attention even though this is contrary to the endogenous goals of the individual (Godijn & Theeuwes, 2003; Van der Stigchel et al., 2009). This approach allows an assessment of the ability to inhibit task-irrelevant threat processing in order to voluntarily shift the spotlight of attention to a task-relevant target (i.e., the ability to inhibit interference from threatening distractors).

Interference from threatening distractors has recently been considered by MacNamara and Hajcak (2010) in an ERP study. They presented participants with two pairs of pictures simultaneously; one pair was presented horizontally to the left and right of central fixation and one pair was presented vertically above and below central fixation. A stimulus pair consisted of either two aversive pictures or two neutral pictures. A cue was presented prior to the onset of the four images to indicate which picture pair was the target (the uncued picture pair was the distractor). Participants were instructed to indicate whether the two pictures in the target pair were the same or different. MacNamara and Hajcak (2010) measured the LPP (the late positive potential), which is known to be greater for emotional compared with neutral stimuli and is averaged from 400-800 ms post-stimulus onset. They found that, in comparison with control participants, the increase in the amplitude of the LPP in response to an aversive (vs. neutral) target was greater in individuals with GAD, but only when the distractor was neutral. Furthermore, their behavioural data indicated that the error rate was higher for the individuals with GAD compared with control participants on the aversive distractor trials. Taking these findings together, they concluded that the individuals with GAD expended greater attentional resources on threatening targets (as indexed by the LPP) when distractors required minimal attentional resources (i.e. when they were neutral). In contrast, threatening distractors disrupted performance (as indexed by the error rate) and competed for attentional resources to a greater extent compared with neutral distractors and, therefore, it was not possible for individuals with GAD to enhance processing of the threatening target. These findings highlight that threatening distractors compete for attention in anxious individuals even when they are irrelevant to the ongoing task.

Recent neuroimaging studies have provided an insight into the neural structures and mechanisms that may account for increased distractibility by threat in anxiety (Bishop, Jenkins, & Lawrence, 2007). Bishop et al (2007), for example, asked participants to decide whether a string of six letters, superimposed on a task-irrelevant fearful or neutral face, contained the letter X or N. Using fMRI, they found that, among individuals with high levels of trait anxiety, there was reduced activation in areas associated with attentional control (lateral prefrontal cortex and anterior cingulate cortex) in response to task-irrelevant fearful (vs. neutral) faces. Bishop et al., (2007) reported that these findings only held under conditions of low perceptual load. The letter string contained 6 Ns or six Xs in the low perceptual load condition and contained one target letter and five different non-target letters in the high perceptual load condition; thus, search demands were increased in the high perceptual load condition. They concluded that, when the task-relevant stimuli did not occupy all of the attentional resources (i.e. under conditions of low perceptual load), high trait anxious individuals were unable to recruit prefrontal control mechanisms to prevent the allocation of attentional resources to task-irrelevant threat distractors.

The findings presented so far suggest that impaired inhibition of threat is a general deficit that occurs in all anxious individuals. However, further research suggests that there are individual differences in attentional control within an anxious population and that these individual differences moderate the ability to inhibit threat processing. For example, Reinholdt-Dunne et al. (2009) obtained a behavioural measure of attentional control using the Attentional Network Task (ANT), which assesses alerting, orienting and executive attention. They asked participants to complete an emotional Stroop task with words (threat, positive or neutral) and faces (angry, fear, happy or neutral). They found that individuals with high levels of trait anxiety were slower to colour name emotional faces compared with neutral faces, but only if they displayed low attentional control (there was no such effect in individuals with low levels of trait anxiety or in either group for word stimuli). Similarly, Derryberry and Reed (2002) found that high (vs. low) trait anxious individuals were slower to disengage from threatening stimuli, where this effect was greatest in anxious individuals with low levels of self-reported attentional control. While these findings are inconsistent with the notion of a general deficit in attentional control in anxiety (Eysenck et al., 2007), they are consistent with the notion that attentional (or effortful) control is a self-regulative temperamental trait that can be used to override an attentional bias to threat in anxious individuals (Lonigan et al., 2004). Thus, it is possible that impaired inhibition of threat is only apparent in a subsection of the anxious population.

In line with the hypotheses from ACT (Eysenck et al., 2007), there is converging evidence from RT, eye movement, ERP and fMRI data to indicate that there is impaired inhibition of threat in anxiety and that this disrupts performance in ongoing tasks. Impaired inhibition occurs even when the threatening stimulus is a task-irrelevant distractor (Bishop et al., 2007; MacNamara & Hajcak, 2010) and/or when it is presented in a different spatial location to the ongoing task (Derakshan et al., 2009; Georgiou et al., 2005). However, there is a notable point of departure between the findings reported by Bishop et al (2007) and ACT. While ACT predicts that attentional control would be particularly impaired under conditions that place high demands on processing resources, the fMRI findings indicate that attentional control is particularly impaired under conditions that place low demands on processing resources (Bishop, 2009). This apparent discrepancy may reflect the focus on working memory load (i.e., demands on the central executive in tasks requiring the inhibition and shifting functions of attentional control) in ACT and the focus on perceptual load in the work of Bishop et al., (2007). For example, if attentional resources are directed towards task-irrelevant threat to a greater extent under conditions of low (vs. high) perceptual load, then it is plausible that the demands on the central executive will actually increase under these conditions because greater effort will be required to inhibit threat processing or shift attentional resources away from the task-irrelevant threat. Although the current work makes no attempt to distinguish between these propositions, it is important to keep in mind that they at least concur in highlighting that demands on attention and processing resources (e.g., the complexity of the visual environment) affect the extent to which anxious individuals display impaired inhibition of threat. This is an important point because it raises the possibility that although anxiety may be characterised by impaired inhibition of threat, this characteristic may not be apparent in all threat-related scenarios.

While the existing literature has been important in highlighting that there is an impairment in inhibiting threat processing in anxiety, there is relatively limited evidence considering interference from threatening distractors that are both task-irrelevant and presented in a different spatial location to the ongoing task. The few studies that have considered this issue have found evidence to suggest that anxious individuals allocate attentional resources to threatening distractors (MacNamara & Hajcak, 2010) and that this may occur due to reduced recruitment of prefrontal control mechanisms (Bishop et al., 2007). However, the principal measures of interest in these studies either have poor temporal resolution (i.e. fMRI, Bishop et al., 2007) or occur at a relatively late stage of stimulus processing (i.e. the LPP component averaged from 400-800 ms in MacNamara & Hajcak, 2010). Therefore, it remains unclear whether the allocation of attentional resources to threatening distractors occurs as a consequence of early attentional capture by threat or delayed disengagement from threat at a later stage of stimulus processing.

2.3.2 Delayed Disengagement from Threat

There is growing evidence to suggest that the attentional bias to threat in anxious individuals is better understood in terms of delayed disengagement from threat rather than attentional capture by threat. An emotional version of the spatial cueing paradigm has typically been used to distinguish between these processes. In the original paradigm (Posner, 1980), participants were presented with a neutral peripheral cue which was either congruent (valid cue) or incongruent (invalid cue) with the location of a subsequent target. Posner (1980) reported that RTs to respond to the target were facilitated by valid cues and delayed by invalid cues. In the emotional version of the spatial cueing paradigm, the target stimuli are preceded by threatening, positive or neutral cues. Fox et al (2001, 2002) argued that anxiety-related attentional capture by threatening stimuli would be reflected in quicker RTs to detect or categorise the target following valid threat cues in individuals with high levels of anxiety (vs. non-anxious individuals). Conversely, individuals with high levels of anxiety would be slower (vs. non-anxious individuals) to respond to the target following invalid threat cues if they had difficulties in disengaging attention from threatening stimuli.

Using this rationale, evidence from the spatial cueing paradigm indicates that anxiety is associated with slowed disengagement from angry faces in individuals with high levels of state anxiety (Fox et al., 2001), social threat words in individuals with social phobia (Amir, Elias, Klumpp, & Przeworski, 2003) and emotional (angry and happy) faces in individuals with high levels of trait anxiety (Fox et al., 2002). In other words, anxious individuals (vs. non anxious individuals) were slower to respond to the target when it was preceded by an invalid threatening or emotional cue. These studies found no evidence to suggest that attention was captured by angry faces in individuals high in state or trait anxiety or individuals with social phobia (i.e. anxiety was not associated with faster responses to the target following valid threatening cues). Thus, in contrast with the findings reported from the dot probe paradigm, research from studies using the spatial cueing paradigm do not support the proposition that anxious individuals rapidly orient towards threatening stimuli at an early stage of stimulus processing.

Further research by Koster and colleagues (Koster, Crombez, Verschuere, & De Houwer, 2006; Koster, Verschuere, Crombez, & Van Damme, 2005) has highlighted similarities between the findings from the dot probe and spatial cueing paradigms. They raised the possibility that the anxiety-related attentional bias to threat in the dot probe paradigm could occur as a result of either rapid engagement with threat when the probe appeared in the location of the threat stimulus or slowed disengagement from threat when the probe appeared in the opposite location to the threat stimulus. In order to explore these two possibilities, they compared trials in which threat-neutral and neutral-neutral stimulus pairs were presented. They argued that rapid engagement with threat would be reflected in responses that were faster when the probe replaced the threat stimulus in the threat-neutral condition compared with when the probe replaced a neutral stimulus in the neutral-neutral condition; slowed disengagement from threat would be reflected in responses that were slower when the probe replaced the neutral stimulus in the threat-neutral condition compared with the neutral-neutral condition. Using this rationale, they showed that high trait anxious individuals were slower to respond to the probe when it replaced the neutral picture in a stimulus pair containing a neutral and threatening picture compared with a stimulus pair containing two neutral pictures. They concluded that anxious individuals found it difficult to disengage their attention from threat.

As outlined above, it is important to present task-irrelevant threat stimuli when considering processes related to attentional control (i.e. attentional capture and disengagement). In the spatial cueing paradigm, the face is a cue that indicates the probable location of the subsequent target and, therefore, it is difficult to regard these stimuli as entirely task-irrelevant. However, eye movement methodologies have recently been used in visual search studies to distinguish between attentional capture and slowed disengagement from threatening distractors in anxiety (Gerdes, Alpers, & Pauli, 2008; Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). With respect to findings of attentional capture, Miltner et al., (2004) presented participants with displays containing either one target (a spider or mushroom) amongst 15 flower distractors or one target and one singleton distractor (a spider target and mushroom distractor or vice versa) amongst 14 flower distractors. Participants were instructed to make a manual keypress response when they detected a pre-specified target. Miltner et al (2004) found that participants with a spider phobia executed eye movements towards singleton spider distractors and singleton mushroom distractors before looking at a target on 30.2% and 10.8% of the trials respectively (12.2% and 14.1% respectively for non-phobic control participants). In line with this finding, they also reported that manual responses to detect a mushroom target were slower in participants with a spider phobia (vs. control participants) when a singleton spider distractor was present in the display (group differences were not observed in the other experimental conditions). These findings suggest that feared distractors captured overt attention (as indexed by eye movements) and interfered with ongoing performance (as indexed by manual detection responses) in anxious individuals. However, note that a recent eye tracking study by Derakshan and Koster (2010) found no evidence to suggest that trait anxiety was associated with facilitated initial orienting (i.e. attentional capture) of visual attention to threatening faces (see further details of this study in Section 3.1.1).

Visual search studies have also reported evidence of a delay in disengaging from threatening distractors in anxious individuals (Byrne & Eysenck, 1995; Gerdes et al., 2008; Rinck et al., 2005). Rinck et al (2005), for example, asked participants to decide whether a target (a spider, beetle or butterfly) was present or absent in displays containing 20 items (the distractors within a display were all spiders, all beetles, or all butterflies). They found that, when a target was presented amongst spider distractors, spider fearful individuals fixated on the distractors for a longer duration and were slower to detect the target (in terms of manual RTs) compared with non-fearful controls. In contrast, when the target was presented amongst butterfly or beetle distractors, there was no significant difference in RTs or gaze duration between the fearful and non-fearful groups. The authors concluded that individuals with high levels of anxiety were slower to disengage their attention from feared objects. Similarly, Byrne and Eysenck (1995) found evidence to suggest that elevated anxiety was associated with delayed disengagement from threatening faces; high trait anxious individuals (vs. low trait anxious individuals) were significantly slower to detect a happy target when it was presented amongst angry distractors compared with neutral distractors. In contrast, Derakshan and Koster (2010) found no evidence to suggest that trait anxiety was associated with delayed disengagement of visual attention from angry faces (as indexed by eye movements; see Section 3.1.1).

In summary, there is accumulating evidence to suggest that anxiety is characterised by delayed disengagement from threat. Importantly, the consistency between studies raises the possibility that many of the findings of selective attention to threat outlined in Section 2.2.1 can be attributed to delayed disengagement from threat rather than rapid initial orienting towards threat. Thus, while cognitive models of selective attention typically suggest that anxious individuals rapidly allocate attentional resources towards threatening stimuli (e.g. Beck & Clark, 1997; Mathews & MacLeod, 1998; Mogg & Bradley, 1998; Williams et al., 1997), the empirical evidence is more compatible with the notion that anxiety is associated with impaired attentional control (e.g., Eysenck et al., 2007) and that anxious individuals allocate attentional resources towards threatening stimuli for an extended duration of time and find it difficult to shift attention away from threat.

2.3.3 Summary

This section has provided evidence to indicate that there is impaired attentional control in anxiety. The empirical research suggests that this impairment is associated with impaired inhibition of threat (Derakshan et al., 2009; Mogg et al., 2000), delayed disengagement from threat (Fox et al., 2001, 2002) and, to a lesser extent, attentional capture by threat (Miltner et al., 2004). These findings are largely consistent with recent theoretical models of anxiety (Eysenck et al., 2007; Fox et al., 2001, 2002).

This section has highlighted the importance of assessing these attentional processes by using task-irrelevant threat that is presented in a separate spatial location to the ongoing task to ensure that, in line with ACT, the stimulus-driven and goal-directed attentional systems are placed in direct competition. To date, the empirical evidence indicates that anxiety is associated with a greater allocation of attentional resources to threatening distractors (Bishop et al., 2007; MacNamara & Hajcak, 2010). Research has, thus far, been unable to definitively distinguish between the possibility that that this effect is due to attentional capture by (Miltner et al., 2004) or delayed disengagement from (Rinck et al., 2005) threatening distractors.

In considering these attentional processes in greater detail, it is important to reiterate that attentional control has been defined as the ability to regulate orienting responses (Derryberry & Reed, 2002). Chapter 1 emphasised that orienting is the mechanism by which stimuli are selected for further processing. Therefore, impairments in attentional control should be closely related to the ability to regulate selective attentional processes. Indeed, attentional capture by task-irrelevant threat in anxiety (Miltner et al., 2004) suggests that there is a difficulty in preventing the spotlight of attention landing on a threatening stimulus. A delay in disengaging attention from task-irrelevant threat in anxiety (Rinck et al., 2005) implies that there is a difficulty in shifting the spotlight of attention once it falls on a threatening stimulus. A third possibility, and one that has received less consideration, is that anxiety may be characterised by a difficulty in focusing a spotlight of attention on a task-relevant neutral stimulus when task-irrelevant threatening stimuli are present within a broad attentional beam. Further work is required to directly compare these propositions. Importantly, the latter proposition would suggest that anxious individuals do not necessarily focus a spotlight of attention on task-irrelevant threat; instead, they can be distracted by threat across the visual field. It is likely that the function of this broad allocation of attention would be to remain vigilant for threat and facilitate threat detection (Beck et al., 2005; Eysenck, 1992).

2.4 *Anxiety, Hypervigilance and Threat Detection: Empirical Evidence*

Cognitive models propose that anxiety is characterised by enhanced threat detection (Eysenck, 1992; Eysenck et al., 2007). These models suggest that individuals with high levels of anxiety maximise the chances of detecting threat by being hypervigilant; this is achieved by either maintaining a broad focus of attention or by excessively scanning the environment with numerous eye movements (Beck et al., 2005; Eysenck, 1992). To date, empirical research on threat detection and the distribution of attention in anxiety has been carried out in parallel as two separate lines of enquiry. Visual search studies have been utilised to consider the possibility that there is enhanced threat detection in anxious individuals (Byrne & Eysenck, 1995; Matsumoto, 2010). With respect to hypervigilance and the distribution of attention, theory and research have focused on the notion that a broad focus of attention leads to impairments in attentional control (i.e. increased distractibility; see review by Eysenck et al., 2007). There is, thus far, only a small body of literature considering the purpose of a broad focus of attention in anxiety and the circumstances in which it has a beneficial effect (e.g., in the detection or recall of peripheral stimuli (Keogh & French, 1999; Shapiro & Lim, 1989).

2.4.1 Threat Detection

The visual search paradigm has been employed relatively infrequently in anxiety research (Bar-Haim et al., 2007), yet it is a useful tool for exploring threat detection. There is evidence from RT studies to suggest that search for and detection of evolutionary threats (e.g. snakes and spiders) is enhanced in individuals reporting high levels of fear or phobia for these specific stimuli (Flykt & Caldara, 2006; Öhman, Flykt, & Esteves, 2001; Rinck et al., 2005; Soares, Esteves, Lundqvist, & Öhman, 2009). However, the studies of primary interest in this section are those that have assessed search for threatening faces in individuals with high levels of trait anxiety or social anxiety. Before providing a detailed review of this literature, a preliminary outline of the basic visual search paradigm is required as a context for this research (Donnelly, Hadwin, Menneer, & Richards, 2010).

The Basic Paradigm. In a typical visual search task, participants are asked to search for and indicate the presence or absence of a target stimulus which can be presented with different numbers of distractor stimuli to make displays of different set sizes. Visual search studies typically measure RTs to detect the target as a function of set size. Alternatively, the accuracy of target detection can be considered if the display is presented for limited exposure durations (Müller & Krummenacher, 2006; Wolfe, 1998). Traditional accounts of visual search suggest that a parallel search occurs when increases in set size do not impact upon the speed or accuracy of detecting the target item. In a serial search, locating the target requires the serial deployment of attention and the speed and accuracy of detecting the target item decreases as set size increases (Treisman & Gelade, 1980).

The Guided Search Model (Wolfe, 1994) provides a possible explanation for why some target stimuli are detected using parallel search processes whilst other target stimuli are detected using serial search processes. This model suggests that basic features (e.g. colour, orientation) are represented in parallel in separate feature maps. The level and location of activation in each feature map is dependent on bottom-up information (i.e. provided by distinctive items in a display) and top-down information (i.e. provided by a designated target). These feature maps are then combined to produce an overall activation map. Attention is initially deployed to the point of highest activation in the activation map because this represents the most likely location of the target. A target stimulus that consistently produces the highest level of activation in the activation map, irrespective of set size, will always be the first item to attract attention in a display (i.e. a parallel search). The target will not be the first item to attract attention if the location of highest activation (i.e. the most likely target location) corresponds to a distractor. In this instance, attention is serially redeployed to locations with progressively lower activation until the target is located or the search is terminated.

Typically, the gradient of the search slope (i.e. where RTs are regressed against set size) is used to define the search as either parallel or serial, where shallow search slopes (e.g. 0 ms per item) are believed to be indicative of a parallel search and steep search slopes reflect a serial search. Other researchers have argued that search slopes cannot be used to discriminate between parallel and serial search because search slope gradients lie on a continuum rather than falling into two dichotomous categories (Wolfe, 1998). Furthermore, a shallow search slope can be produced by a serial search mechanism and a steep search slope can be produced by a limited-capacity parallel search mechanism. In the latter case, for example, all of the display items are processed simultaneously, but the fixed amount of attentional resources (or capacity) available means that the amount of resource per item decreases as set size increases. This limitation in resource per item leads to an increase in the time taken to accumulate information about each item and, therefore, RTs increase as set size increases (Wolfe, 1998). Therefore, it is often argued that search slopes should only be used to consider search efficiency, where shallow slopes represent efficient search (Duncan & Humphreys, 1989; Wolfe, 1998).

Visual Search for Threatening Faces. Studies employing RT measures have found that anxiety is associated with greater speed, accuracy and efficiency in searching for and detecting the presence and absence of angry target faces (Eastwood et al., 2005; Gilboa-Schechtman, Foa, & Amir, 1999; Hadwin et al., 2003; Juth, Lundqvist, Karlsson, & Öhman, 2005; Matsumoto, 2010; Perez-Olivas, Stevenson, & Hadwin, 2008).

A number of anxiety studies have considered the overall speed and accuracy of detecting emotional target faces in displays of constant set size (Byrne & Eysenck, 1995; Gilboa-Schechtman et al., 1999; Juth et al., 2005). Byrne and Eysenck (1995) presented participants with 12 photographic faces; target present displays consisted of an angry or happy target presented amongst emotional or neutral distractors. It is important to note that, although Byrne and Eysenck (1995) interpret their findings in terms of threat detection, they actually used a localisation task. Specifically, participants had to press one of twelve response keys that corresponded to the location of the target face or they had to press the space key to indicate the absence of a target. They found that participants with high levels of trait anxiety were faster to locate an angry target compared with low trait anxious participants (this effect was not observed for happy faces). Similarly, there is evidence to indicate that individuals with high levels of social anxiety detect angry faces with greater speed (Gilboa-Schechtman et al., 1999) and accuracy (Juth et al., 2005, Experiment 5) compared with happy faces. However, as highlighted by the authors of these studies, it appeared possible that the findings were actually a consequence of slow localisation of the angry target in the participants with low levels of trait anxiety in Byrne and Eysenck's (1995) study and by slowed or inaccurate detection of happy targets in the participants with high levels of social anxiety in the studies conducted by Gilboa-Schechtman et al (1999) and Juth et al (2005).

Further studies have extended these findings by varying set size in order to consider the effect of anxiety on search efficiency as indexed by the gradient and intercept of the search slope (Eastwood et al., 2005; Hadwin et al., 2003; Matsumoto, 2010). These studies indicate that trait anxiety is associated with greater efficiency in detecting the absence of an angry face in high trait anxious children (Hadwin et al., 2003) and; greater efficiency in detecting the presence of an angry face in high trait anxious adults (vs. low trait anxious; Matsumoto, 2010) and adults with social phobia and panic disorder (vs. control participants or individuals with OCD; Eastwood et al., 2005). Matsumoto (2010), for example, presented displays containing 4, 8 or 12 schematic faces and instructed participants to indicate the presence or absence of a discrepant face. Target absent displays contained faces of the same expression (angry, happy or neutral) and target present displays contained one angry or one happy target presented amongst emotional or neutral distractors. They found that, in the context of neutral distractors, the gradient of the search slope was significantly shallower for angry target faces compared with positive target faces in high trait anxious individuals (this effect was not observed in low trait anxious individuals). Furthermore, the search slope for the angry faces was shallower in the high trait anxious group compared with the low trait anxious group. Thus, these studies concur with the notion that there is enhanced threat detection in anxiety.

Summary. The visual search paradigm has been used to consider threat detection in anxiety. There is converging evidence from measures of overall speed (Byrne &

Eysenck, 1995; Gilboa-Schechtman et al., 1999), accuracy (Juth et al., 2005) and search slope gradients and intercepts (Eastwood et al., 2005; Hadwin et al., 2003; Matsumoto, 2010) to indicate that anxiety is associated with greater efficiency in detecting the presence and absence of angry faces. However, it is important to note that the group based design used in many of these studies (i.e., high vs. low anxiety groups) can make it difficult, in some circumstances, to interpret whether these effects were driven by enhanced threat detection in the high anxious group, poor threat detection in the low anxious group, or poor detection of happy faces in the high anxious group (Byrne & Eysenck, 1995; Gilboa-Schechtman et al., 1999; Juth et al., 2005). A potentially more fruitful approach in distinguishing between these explanations is to consider anxiety as a dimensional construct and assess its relationship with target detection for each emotion (see Hadwin et al., 2003).

2.4.2 Hypervigilance and the Breadth of Attention

Few studies have addressed the hypothesis that, prior to threat detection, anxiety is associated with a broad focus of attention and scanning of the visual environment. Keogh and French (1999) considered the breadth of attention as a function of both trait and state anxiety. They presented participants with target stimuli (threatening and non-threatening words) to parafoveal or peripheral regions of the visual field. The participants were instructed to maintain their gaze on the centre of the screen and indicate whether the target appeared in a parafoveal location (i.e., an eccentricity of 2.8°) or a peripheral location (i.e., an eccentricity of 11.5°). Anxious mood state was enhanced in some of the participants; they were instructed to perform a mental arithmetic task and informed that they would take part in an intelligence test (the remaining participants acted as controls). The authors found that the control group were slower to locate peripherally presented targets compared with parafoveal targets. In contrast, RTs did not differ between the parafoveal and peripheral targets in the group that had taken part in the mood manipulation. This effect occurred irrespective of trait anxiety. They concluded that an elevation in anxious mood state is associated with a broadening of the attentional beam and a reduction in the preference to process central (and in this case parafoveal) stimuli. They argued that this broadening of attention is an adaptive response that would occur in high and low trait anxious individuals when exposed to a dangerous situation, with the purpose of enhancing the localisation of potential threats. One difficulty with this interpretation is that the participants exposed to the mood manipulation did not display enhanced localisation of threatening (vs. non-threatening) words; that is, a broad focus of attention offered no apparent benefit in threat localisation.

Additional studies have found that an elevation in the anxious mood state is associated with a broad focus of attention and enhanced detection (Cornsweet, 1969; Shapiro & Johnson, 1987; Shapiro & Lim, 1989) and recall (Solso, Johnson, & Schatz, 1968) of peripheral stimuli. Shapiro and Lim (1989), for example, played participants different pieces of music to manipulate mood and to create anxious and non-anxious groups. They instructed participants to maintain central fixation and presented one green circle in a parafoveal or peripheral location or presented two green circles simultaneously in a parafoveal and peripheral location. In the latter condition, participants were asked to indicate whether they detected the parafoveal or peripheral stimulus first. They found that the non-anxious group detected the parafoveal circle first on 89% of the trials, whereas the anxious group detected the parafoveal and peripheral circles first with equal frequency (51% vs. 49% of the trials). They concluded that central dominance did not occur in the anxious group; in other words, anxiety was associated with a broadening of attention.

Early studies have argued that a broadening of attention in anxiety should be associated with an increased tendency to process task-irrelevant stimuli (Dusek, DeYaeger Kermis, & Mergler, 1975; Dusek, Mergler, & DeYaeger Kermis, 1976; Markowitz, 1969). Markowitz (1969), for example, instructed participants to intentionally learn 12 trigrams. Each trigram was presented with a task-irrelevant incidental stimulus (a positive, negative or neutral word). Anxious mood (i.e. state anxiety) was manipulated by informing participants either that their data would contribute to a measure of average performance on the task (low state anxiety condition) or that performance on the task was related to intelligence (high state anxiety condition). Markowitz (1969) found that high trait anxious participants (referred to as 'sensitisers' in this paper) demonstrated greater incidental learning under conditions of high (vs. low) state anxiety (i.e., they correctly recalled a greater number of the incidental word stimuli). He concluded that high trait anxious participants utilised environmental stimuli to a greater extent when exposed to stressful conditions.

In contrast to the notion of a broadening of attention, further research has assessed the hypothesis that anxious individuals excessively scan the visual environment with numerous eye movements (Freeman, Garety, & Phillips, 2000; Horley et al., 2004). Freeman et al., (2000) presented participants with four types of pictures: a potential threat scene (e.g. a person walking along a path at dusk), a direct threat scene (e.g., a dog attacking a person), a hidden threat scene (e.g. a person by the side of a path under a bridge about to jump out at a passer-by) or a happy event (e.g., a smiling family scene). This was a free-viewing task in which visual scan paths were recorded as participants looked at the pictures. They hypothesised that anxiety would be associated with: excessive scanning (indexed by “the number of areas gazed upon”) on hidden and potential threat pictures and; enhanced threat detection (indexed by the time taken to look at the threat in the hidden threat trials). They found no evidence to support either of these hypotheses in individuals with GAD and concluded that there was neither excessive scanning nor enhanced threat detection in this group of anxious individuals. This finding is inconsistent with the notion that anxious individuals adopt a hypervigilant approach in which they scan the environment with numerous eye movements to enhance threat detection (Eysenck, 1992). It is also seemingly inconsistent with visual search studies, which indicate that anxiety is associated with greater efficiency in detecting threat (Matsumoto, 2010); one possible explanation for this discrepancy is that, unlike the majority of the visual search studies, the index of threat detection employed by Freeman et al. (2000) actually required that the participant had located the threat.

Contradictory findings were reported in a further eye tracking study by Horley et al (2004) in which there was evidence of excessive scanning of some facial expressions in individuals with social phobia. In this study, participants were presented with a picture of a neutral, sad, angry or happy face for 10 seconds and instructed to look at it in any manner they chose. Horley et al (2004) found that the scanpath length (the total distance covered by the eyes) was greater for individuals with social phobia (vs. control participants) when viewing angry or neutral faces. They concluded that excessive scanning of negative faces in social phobia is likely to reflect hypervigilance for signs of negative social evaluation.

In summary, there is evidence to indicate that anxious individuals adopt a broad focus of attention and that this is associated with enhanced localisation, detection and recall of peripheral stimuli (Keogh & French, 1999; Shapiro & Lim, 1989; Solso et al., 1968). There is, thus far, mixed evidence related to the proposition that anxiety is associated with excessive scanning of the visual environment (Freeman et al., 2000; Horley et al., 2004).

2.4.3 Summary

This section highlighted evidence of enhanced threat detection in anxious individuals (Byrne & Eysenck, 1995; Eastwood et al., 2005; Matsumoto, 2010). It also reviewed evidence to suggest that anxiety is associated with a broad focus of attention and that a potential benefit of distributed attention is the enhanced detection and recall of peripheral stimuli (Keogh & French, 1999; Markowitz, 1969; Shapiro & Lim, 1989). From an empirical perspective, the relationship between these two findings is unknown; specifically, it is currently unclear whether the broad focus of attention in anxiety is associated with enhanced threat detection. Furthermore, the cognitive mechanisms that might underlie enhanced threat detection within a broad attentional beam have not been considered. While Keogh and French (1999) found evidence of a broad focus of attention and enhanced localisation of peripheral stimuli, this effect occurred irrespective of whether the peripheral stimuli were threatening or non-threatening words. However, Keogh and French (1999) and the visual search studies outlined in this section considered detection and localisation of singleton threats. It is possible that the benefits of a broad focus of attention would be particularly apparent when threatening stimuli occur in multiple locations across the visual field. A broad (vs. narrow) focus of attention would allow information about the presence of threat to be accumulated from more than one location. Therefore, further work is required to consider the relationship between the breadth of attention and threat detection in anxiety in an attempt to understand the cognitive mechanisms and attentional processes that enable anxious individuals to monitor and detect threat with greater efficiency than non-anxious individuals.

2.5 An Overview of the Current Programme of Work

This chapter reviewed empirical evidence supporting the theoretical propositions that anxiety is associated with a selective attentional bias to threat (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997), impaired attentional control (Eysenck et al., 2007; Fox et al., 2001, 2002) and hypervigilance for threat and enhanced threat detection (Beck et al., 2005; Eysenck, 1992). This chapter also highlighted that further work is required to consider these theoretical propositions in greater detail.

In terms of selective attention to threat, it is relatively clear that individuals with high levels of anxiety preferentially allocate attentional resources to threatening (vs.

neutral) stimuli (Bradley et al., 1998; Garner et al., 2006; Mueller et al., 2009) and this is typically interpreted as evidence of a selective attentional bias. However, given that selection requires that the spotlight of attention is directed to the location of interest (Cave & Bichot, 1999; Posner et al., 1980), it is surprising that very few studies consider threat localisation in anxiety. Therefore, it is currently unclear whether anxiety influences the efficiency with which a limited capacity cognitive system locates high priority threat signals amongst competing visual inputs in order to select them for further processing.

With respect to impaired attentional control, there is evidence to indicate that anxious individuals have difficulties inhibiting (Bishop et al., 2007; Derakshan et al., 2009; MacNamara & Hajcak, 2010; Mogg et al., 2000) or disengaging from threatening stimuli (Fox et al., 2001, 2002). The purpose of attentional control is to regulate orienting responses (Derryberry & Reed, 2002) and, by implication, selective attentional processes. However, research with task-irrelevant threatening distractors (Miltner et al., 2004; Rinck et al., 2005) has not conclusively identified the selective attentional processes that are critical to the association between anxiety and impaired attentional control. For example, it is possible that anxiety is associated with a difficulty in preventing the spotlight of attention being directed to threat (attentional capture), a difficulty in shifting the spotlight of attention away from threat (delayed disengagement) or a difficulty in focusing a spotlight of attention on task-relevant stimuli when threat is present in other locations (i.e., an inability to inhibit threat within a broad attentional beam).

Finally, there is evidence to suggest that anxiety is associated with enhanced threat detection (Byrne & Eysenck, 1995; Matsumoto, 2010) and a broad focus of attention (Keogh & French, 1999; Markowitz, 1969; Shapiro & Lim, 1989). Empirically, the relationship between threat detection and the breadth of attention is unclear. For example, previous research has not considered how a broad focus of attention might facilitate threat detection in anxious individuals.

Each of these issues can be addressed by considering the eye movement behaviour of anxious and non-anxious individuals. Moving the eyes to sample a visual scene is a default setting in cognitive-visual tasks and the natural environment (Liversedge & Findlay, 2000) and the relationship between overt and covert attention is well-established (Hoffman & Subramaniam, 1995). In line with the spotlight metaphor of attention, the eye movement system serves as a location-based selection mechanism whereby visual stimuli within foveal vision receive the highest processing priority due to enhanced visual acuity in this region. Indeed, due to the constraints of the retinal input to the visual system, it is a physiological necessity to direct foveal vision towards significant stimuli if selective attention is required to process these stimuli in greater detail (Findlay & Gilchrist, 2003). Peripheral vision provides information about the location of potentially significant stimuli and, therefore, guides subsequent eye movements (Findlay & Gilchrist, 2003). Before generating predictions about how selective attention to threat, impaired attentional control and hypervigilance for threat might be reflected in eye movement behaviour, it is important to provide a physiological and conceptual account of the oculomotor system.

2.5.1 The Oculomotor System

The physiological characteristics of the oculomotor system and the brain activity associated with executing saccades and maintaining fixation have been described extensively. Saccades are fast rotations of the eye which occur 3-4 times per second and are interspersed with fixation periods in which the eye remains stationary (Findlay & Gilchrist, 2003). There are cells in the brainstem (burst cells and omnipause cells) related to saccades and fixations (Findlay & Walker, 1999; Liversedge & Findlay, 2000); there is activity in burst cells during saccades and in omnipause cells during fixations. It is likely that this brainstem circuitry is related to automatic processes such as using the oculomotor muscles to rotate the eye (Findlay & Walker, 1999).

A brain area that has received considerable attention as an important component in the oculomotor system is the superior colliculus of the midbrain, which receives inputs from cortical and sub-cortical visual regions and triggers saccades via its projections to the brainstem premotor circuitry (Trappenberg, Dorris, Munoz, & Klein, 2001). Munoz and colleagues (Munoz & Istvan, 1998; Munoz & Wurtz, 1993a; Munoz & Wurtz, 1993b; Munoz & Wurtz, 1995a; Munoz & Wurtz, 1995b) considered the role of the superior colliculus in the generation and suppression of saccades in monkeys. They reported that fixation cells and two types of saccade-related cells, burst cells and buildup cells, could be found in the superior colliculus. Specifically, fixation cells were located in the rostral pole of the superior colliculus; burst cells and buildup cells were located in all regions of the superior colliculus except the rostral pole. They suggested that, during periods of visual fixation, fixation cell activity suppressed the generation of saccades due to inhibitory connections between the fixation cells and saccade-related cells (see also, Trappenberg et al, 2001). The balance of activation between the fixation cells and buildup cells determined whether the animal fixated or made a saccade.

Related to the disengagement and engagement components of visual orienting, they proposed that saccade preparation would be associated with disengagement of attention from the current location (i.e. a gradual decrease in fixation cell activity) and engagement of attention at a new location (i.e. a simultaneous gradual increase in buildup cell activity approximately 100 ms prior to saccade onset). Due to the strong inhibitory connections between the fixation cells and the burst cells, the termination of fixation cell activity would lead to the disinhibition of saccade-related activity and, therefore, burst cell activity would occur approximately 25 ms prior to saccade onset.

A number of computational models have been developed to account for the role of the superior colliculus in saccade generation (Meeter, Van der Stigchel, & Theeuwes, 2010; Trappenberg et al., 2001). These models highlight that, due to its extensive connections with cortical and sub-cortical regions of the brain, the superior colliculus is able to integrate endogenous and exogenous inputs (Meeter et al., 2010; Trappenberg et al., 2001). Endogenous inputs are based on goal-directed factors such as task instructions and the intentions or expectations of the observer; exogenous inputs depend on low-level sensory properties of the stimuli in the visual environment (Meeter et al., 2010; Trappenberg et al., 2001). Meeter et al., (2010) argued that the integration of these endogenous and exogenous inputs is crucial in determining the target of the subsequent saccade. The target of an endogenous saccade will be a stimulus that is required for and relevant to the ongoing task and the target of an exogenous saccade will be a stimulus that captures oculomotor attention irrespective of the observer's goals and expectations (Godijn & Theeuwes, 2002).

In a related model of saccade generation, Godijn and Theeuwes (2002) argued that it is essential to spatially separate endogenous and exogenous sources of information in order to determine whether a saccade is endogenous or exogenous. This Competitive Integration Model (Godijn and Theeuwes, 2002, 2003) suggests that mutual inhibition occurs when two spatially remote locations are activated by competing exogenous and endogenous sources of information. The activity associated with the endogenous and exogenous stimuli race to reach the threshold required for saccade generation and the winner of the race determines the location of the saccade. The endogenous stimulus can only reach the required level of activation if the exogenous stimulus is inhibited through top-down processes. Lateral inhibition of activation between the endogenous and exogenous stimuli extends the time required to reach the threshold level of activation and, therefore, saccade latencies to the endogenous stimulus are delayed.

An alternative framework of saccade generation was proposed by Findlay and Walker (1999) in the form of a five-level information processing model (see Figure 2.1). Although this model was set within the physiological background of saccadic eye movements (e.g., the brainstem circuitry and superior colliculus), its main focus was on describing a hierarchy of information processing levels, where automatic processes operate at the lower levels (Levels 1-3) and cognitive influences operate at the higher levels (Levels 4 and 5). Their model is comprised of descending influences such that higher levels can have an impact on lower levels, but not vice versa. They proposed that there are two parallel components of the oculomotor system: a ‘When’ system that influences the timing and duration of fixations and a ‘Where’ system that influences the direction and amplitude of saccades.

Level 1 of Findlay and Walker’s (1999) model involves the transmission of motor commands to the oculomotor muscles in the eye. At Level 2, there are inhibitory connections between a fixate centre and a move centre such that a decrease in fixate centre activity below a threshold results in the generation of a saccade. The direction and amplitude of the saccade is determined by activity in a spatial map. Specifically, inhibitory connections between different locations in the spatial map ensure that a salience peak occurs in one location in a winner-take-all manner and that the saccade is directed to this location. Visual events influence the oculomotor system at Level 3 of the model; central visual events affect the fixate centre with visual onsets promoting fixation and visual offsets promoting disengagement. The move centre and the direction/amplitude of saccades are affected by peripheral visual events due to an increase in activity in the corresponding location in the spatial map. Findlay and Walker (1999) highlighted that peripheral visual events could also enhance activity in the fixate centre and they proposed that the physiological basis of this effect would be that peripheral stimuli activate fixation cells that exist beyond the rostral pole of the superior colliculus.

Findlay and Walker (1999) proposed that although Level 4 of their model is affected by high level cognitive factors, it is ‘automated’ and occurs without conscious awareness. In the Level 4 ‘Where’ system, cognitive factors influence the spatial map such that it is more likely that saccades will be executed to particular locations (‘spatial selection’) or particular visual features (‘search selection’). In the Level 4 ‘When’ system, cognitive factors influence the duration of fixations to ensure that sufficient visual information is accumulated for the task at hand. Finally, Level 5 of the model involves the generation of voluntary saccades or the voluntary suppression of saccades that have been programmed at lower automatic levels of the model. Decisions about the spatial locations or visual features that are of interest will be made at Level 5 and will have descending influences on Level 4 spatial selection and search selection.

Figure 2.1 has been removed for copyright purposes

Figure 2.1. A model of saccade generation (from Findlay & Walker, 1999, p.662).

2.5.2 Eye Movements and Attentional Biases to Threat in Anxiety

Physiological and information processing accounts of oculomotor control and saccade generation can be used to explore how attentional biases in anxiety affect eye movements when there are threatening stimuli in the environment. This section will primarily use Findlay and Walker's (1999) model to generate predictions about eye movement behaviour in individuals with high levels of anxiety in relation to selective attention to threat, impaired attentional control and hypervigilance for threat. Findlay and Walker's (1999) model provides a useful framework because it highlights the role of cognitive factors (i.e., threat processing) in saccade generation. Additionally, the models of saccade generation that focus on the integration of exogenous and endogenous inputs to the superior colliculus (e.g., Godijn & Theeuwes, 2002, 2003; Meeter et al., 2010; Trappenberg et al., 2001) are likely to be especially pertinent in understanding the relationship between anxiety and impaired attentional control.

If the anxiety-related threat bias is characterised by the selective allocation of attentional resources to threatening stimuli (e.g., Beck & Clark, 1997; Williams et al., 1997), then this should be evident in the search decisions that are generated at Level 4 and Level 5 of Findlay and Walker's (1999) model. Specifically, individuals with high levels of anxiety (vs. individuals with low levels of anxiety) should be biased to search for threat and this will influence activity in Findlay and Walker's (1999) spatial map such that there is an enhanced or more rapid peak in activity at the locations corresponding to threatening stimuli. Given that saccade triggering is more likely if there is increased activity in the spatial map, this should lead to fast and accurate orienting to the source of threat in anxious individuals. If the peak in activity in the spatial map consistently corresponds to threatening stimuli irrespective of the complexity of the visual environment, then individuals with high levels of anxiety will demonstrate an increased ability to localise threat. This will ensure that the limited capacity cognitive system is more highly tuned to select high priority threat signals for further processing in anxiety.

If the anxiety-related threat bias occurs as a consequence of impaired attentional control (e.g., Eysenck et al., 2007), then this should be reflected in voluntary processes at Level 5 of Findlay and Walker's (1999) model. Level 5 involves the voluntary generation or suppression of saccades and decisions about whether to move the eyes or fixate. In terms of the Competitive Integration Model of saccade generation (Godijn & Theeuwes, 2002, 2003; Meeters et al., 2010), these processes would involve using top-down control to inhibit activation from exogenous threatening stimuli in order to make it possible to generate and execute an endogenous saccade to a task-relevant neutral stimulus.

If the impairment in attentional control leads to attentional capture by threat, then individuals with high levels of anxiety should be unable to suppress exogenous saccades to threatening distractors presented in parafoveal or peripheral locations. Alternatively, individuals with high levels of anxiety may find it difficult to voluntarily execute endogenous saccades to task-relevant neutral stimuli in the presence of threatening distractors; this effect may be specific to threats presented within foveal vision or it may extend to threats in parafoveal and peripheral locations. Threatening distractors presented at central locations may promote fixation by enhancing fixation cell activity to a greater extent in anxious individuals and, therefore, lead to a difficulty disengaging from threat. Specifically, anxiety should be associated with a delay in suppressing this fixation cell activity below the threshold level required to generate an endogenous saccade to a task-relevant neutral stimulus. Threatening distractors presented outside foveal vision may delay voluntary saccades to task-relevant neutral stimuli for two reasons. Firstly, it is possible that the search decision and search selection mechanisms (Levels 4 and 5 in Findlay & Walker's model) are still incorrectly biased towards searching for threat in anxiety despite the presence of conflicting task demands. Therefore, anxiety would be associated with a greater level of competition and more time-consuming conflict resolution between threatening distractors and task-relevant neutral stimuli in Findlay and Walker's (1999) spatial map. Secondly, it is possible that, like central threatening distractors, peripheral and parafoveal distractors also promote fixation to a greater extent in anxious individuals due to enhanced activity in the fixation cells that exist beyond the rostral pole of the superior colliculus.

If the anxiety-related threat bias is characterised by hypervigilance for threat (e.g., Eysenck, 1992), then this would be a strategy implemented at Levels 4 or 5 of Findlay and Walker's (1999) model. Anxious individuals may voluntarily suppress saccades and promote fixation in order to maintain a broad focus of attention and ensure that, in terms of spatial selection, the entire visual field is selected. Alternatively, they might voluntarily execute numerous saccades in order to scan the environment for threat and ensure that the duration of fixations and the extent of cognitive processing is minimised until threat is located.

2.5.3 Summary and Research Questions

The vast majority of the literature on anxiety and attention has utilised RT measures in isolation; these measures are limited because they can only indicate the time taken to complete a task and they are unable to elucidate the processes or mechanisms that underlie the selection, inhibition and detection of threat. In contrast, a consideration of the eye movement behaviour of anxious individuals can provide further insight into the spatial and temporal characteristics of threat processing in anxiety. In relation to visual search tasks, for example, Zelinsky and Sheinberg (1997) argued that eye movements describe the spatiotemporal process of search, whereas RTs to detect the target only provide information about the completion of the search process. Although there is a growing literature on eye movements in anxiety (e.g., Derakshan et al., 2009; Garner et al., 2006; Mogg et al., 2000, 2007), this area remains relatively under-researched.

It is argued in this thesis that an understanding of the oculomotor system is likely to be both important and beneficial to testing and extending the conceptual frameworks of anxiety and attention. Eye movement measures, in conjunction with the use of appropriate paradigms, have the potential to provide information about the processes and mechanisms involved in the anxiety-related threat bias. It is argued that localisation is a mechanism that underlies attentional selection and, therefore, Experiment 1 (Chapter 3) considered selective attention to threat by assessing whether individuals with high levels of anxiety were able to rapidly and accurately move their eyes towards (i.e. locate) threatening stimuli. Experiment 2 (Chapter 4) used an eye movement paradigm to distinguish between the different attentional processes that could account for an inability to inhibit threat processing in anxiety (e.g., attentional capture or delayed disengagement from task-irrelevant threat). This experiment considered whether individuals with high levels of anxiety were unable to suppress exogenous saccades to threatening distractors and/or were slow to execute endogenous saccades towards task-relevant stimuli in the presence of threatening distractors. Experiment 3 (Chapter 5) aimed to establish whether enhanced threat detection in anxiety occurred within a broad focus of attention with few eye movements or a narrow focus of attention with numerous eye movements. This experiment considered the possibility that if anxious individuals maintain a broad focus of attention, then they may be able to integrate information from multiple threats presented in different locations across the visual field in order to facilitate threat detection. Experiment 4 (Chapter 6) explored the possibility that, contrary to the notion of selective attention to threat, individuals with high levels of anxiety would find it difficult to rapidly and accurately move their eyes towards (i.e., locate) a single threat if multiple threats were present in the visual environment.

Chapter 3 : Anxiety and the Localisation of Threatening and Non-Threatening Faces

3.1 Introduction

Several conceptual frameworks of anxiety and attention propose that anxiety is associated with selective attention to threat (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). Selective attention involves orienting attentional resources to the location of interest (Yiend, 2010) and, therefore, a selective attentional bias to threat requires the rapid and accurate localisation of threatening stimuli. The principal aim of this study was to assess whether anxiety is associated with enhanced localisation of threatening stimuli using a visual search paradigm and an eye movement methodology.

3.1.1 The Visual Search Paradigm

Visual search studies in anxiety research have typically been used to assess threat detection by measuring RTs to make a key-press response (Byrne & Eysenck, 1995; Matsumoto, 2010). In contrast, eye movement measures have been employed in visual search studies outside the field of anxiety to assess target localisation (Brown, Huey, & Findlay, 1997; Findlay, 1997; McSorley & Findlay, 2001). This task requires participants to look at the target as quickly and accurately as possible, where the target is present on every trial. Some researchers suggest that target detection and target localisation involve similar search processes (Sagi & Julesz, 1985). Others suggest that target localisation provides a more accurate measure of search efficiency because it is not associated with a tendency to make premature decisions about the presence or absence of a target (Dukewich & Klein, 2009). On a more practical level, Dukewich and Klein (2009) argued that searching in everyday situations typically involves locating an item that is known to be present, rather than deciding whether an item is present or absent.

A number of visual search studies have used eye movement measures to consider search for threatening faces among healthy individuals (Calvo, Nummenmaa, & Avero, 2008; Reynolds, Eastwood, Partanen, Frischen, & Smilek, 2009) or search for spiders and snakes among individuals who are fearful of spiders/snakes (Miltner et al., 2004; Rinck et al., 2005). Reynolds et al (2009), for example, presented participants with displays of different set sizes containing one negative or positive schematic target face presented amongst neutral distractors. Participants were instructed to indicate with a manual response whether the discrepant face in each display was positive or negative. They measured the number of fixations and the time taken prior to first target fixation as a function of set size. They found that the number of fixations and the time taken prior to first target fixation increased with increasing set size. They also found that negative target faces were fixated more rapidly and after fewer fixations compared with positive target faces and that this difference increased with increasing set size; resulting in a shallower search slope for negative faces. The shallower search slope suggests that it is easier to orient towards and select a negative face compared with a positive face as the complexity of the visual environment and the demands on the selective attentional mechanism increase (i.e. with the addition of distractors). Indeed, Reynolds et al. (2009) concluded that negative faces guide attention more efficiently compared with positive faces.

Increased search efficiency for angry faces has not always been replicated in eye movement studies (Calvo, Avero, & Lundqvist, 2006; Calvo et al., 2008; Hunt, Cooper, Hungr, & Kingstone, 2007). Calvo et al (2008), for example, presented an angry, happy, disgusted, surprised, fearful or sad target face amongst six neutral distractors. Participants were asked to indicate with a manual response whether a discrepant face was present or absent. They found that happy, disgusted and surprised target faces were fixated more rapidly and following fewer fixations compared with angry, sad and fearful target faces. Thus, there is currently insufficient evidence to conclude that healthy individuals orient to threatening faces with greater speed and accuracy compared with non-threatening faces (or vice versa). However, anxiety should moderate search for and localisation of threatening faces if there is a selective attentional bias to threat (e.g., Beck & Clark, 1997; Williams et al., 1997).

A recent study considered anxiety and concurrently measured eye movements during a visual search detection task (Derakshan & Koster, 2010). Derakshan and Koster (2010) presented eight faces (angry, happy or neutral) in peripheral locations and instructed participants to press a button if there was a discrepant face. They assessed whether anxiety affected initial orienting to threat by considering eye movements prior to the first fixation on the target face. They found that, although all participants fixated on emotional crowds more often and for longer compared with neutral crowds, this effect was not modulated by trait anxiety. Furthermore, they found no evidence to indicate that trait anxiety was related to the speed of fixating threatening targets. They concluded that the threat bias in anxiety is neither associated with delays in disengaging visual attention from threat nor does it facilitate initial orienting of visual attention to threat. However, they did report that the time taken to manually respond to the target and the number of crowd fixations after the first target fixation was greater in high (vs. low) trait anxious individuals when an emotional target was presented amongst emotional distractors. They concluded that, following first fixation on the target, there was an impairment in target processing efficiency in anxiety. Although Derakshan and Koster (2010) found no evidence to indicate that anxiety affected initial orienting or disengagement of visual attention from threat during a detection task, it remained possible that these effects would be apparent under experimental conditions that explicitly require the localisation of threatening faces.

3.1.2 The Current Study

The current study tested the prediction that anxiety is associated with enhanced localisation of threatening (but not non-threatening faces). Individuals with high levels of anxiety should be able to locate threatening faces with greater speed, accuracy and efficiency compared with non-anxious individuals if anxiety is characterised by a selective attentional bias to threat. The purpose of enhanced localisation would be to ensure that the area of highest visual acuity, the fovea, was directed to high priority threat signals such that they could be processed in more detail. It would also ensure that low priority non-threat signals in the environment received minimal attentional processing. A visual search task was used to assess localisation; participants were presented with a single upright target face (threatening or non-threatening) presented amongst varying numbers of inverted distractor faces. In line with previous visual search studies measuring eye movements (e.g., Brown et al., 1997; Findlay, 1997), participants were required to look at the target as quickly and accurately as possible and the target was present on every trial.

To consider localisation performance, the current study primarily focused on the accuracy and latency of first saccades that landed on target faces presented in peripheral regions of the visual field (see Findlay, 1997 for a similar approach). These initial eye movement measures were interpreted as indicators of search efficiency (in line with McSorley & Findlay, 2001; Wolfe, 1998) where fast and accurate first saccades were indicative of an efficient search. However, Reynolds et al (2009) argued that measures of first saccade accuracy are limited because enhanced attentional guidance by one target (e.g. an angry face) compared with another target (e.g. a neutral face) may emerge slowly over time. Therefore, the current study also considered individual differences in global eye movement measures which encompassed all saccades within each trial (e.g. the total time taken to locate the target).

There were two further manipulations that allowed a consideration of the parameters of enhanced localisation and selective attention to threat in anxiety. Firstly, by manipulating set size it was possible to assess search slope gradients as an additional measure of the efficiency of locating threatening and non-threatening faces. Search slope measures provide a particularly meaningful index of an individual's ability to assign processing priority to a target and ignore non-targets as the complexity of the visual environment increases (i.e., as the number of non-targets increases). If anxiety is characterised by an ability to selectively attend to threat regardless of the complexity of the visual environment, then this should be reflected in a shallow search slope where the speed and accuracy of locating a threat is unaffected by the number of non-threats in the environment.

Secondly, the eccentricity of the target was manipulated (i.e., parafoveal or peripheral targets) because it is widely acknowledged that visual search performance deteriorates, in terms of accuracy and RTs, as the retinal eccentricity of the target increases (Carrasco, Mclean, Katz, & Frieder, 1998; Meinecke & Donk, 2002; Wolfe, O'Neill, & Bennett, 1998). Carrasco et al (1998) argued that this eccentricity effect can be explained by the physiological constraints of the visual system, such as a gradual decline in spatial resolution as a function of retinal eccentricity. These findings raise the possibility that the attentional bias to angry faces in anxious individuals will become more apparent as target eccentricity decreases because the quality and quantity of information extracted from threatening stimuli should be greater if they are presented in parafoveal locations compared with peripheral locations.

Thus, the first aim of the study was to consider whether the speed and accuracy of locating threatening faces presented in peripheral regions of the visual field was influenced by anxiety as indexed by first saccade and global eye movement measures. It was predicted that anxiety would be associated with greater speed and accuracy in locating threatening (but not non-threatening faces) and, furthermore, that this would be evident as early as the first saccade. The second aim was to employ search slope measures to assess whether anxiety was related to an ability to localise threat irrespective of the number of distractors in the visual field. It was predicted that anxiety would be associated with shallower search slopes for threatening (but not non-threatening) faces. The third aim was to assess the possibility that enhanced localisation of threatening faces in anxiety, as indexed by the accuracy and latency of the first saccade, would be particularly evident in visual search displays in which targets were presented in parafoveal locations.

3.2 General Method

Before providing specific methodological details related to the current experiment, this section will outline details that are consistent across the experiments presented in this thesis.

3.2.1 Participants

Healthy adults participated in all studies for course credit or a small monetary incentive. All participants had normal or corrected-to-normal vision. Participants provided informed written consent (see Appendix A for examples of the consent and debriefing forms).

3.2.2 Stimuli and Apparatus

Display items were photographic colour faces from the NimStim face set (Tottenham et al., 2009) displaying angry, happy and neutral expressions. The 16 most reliable models (8 male; 8 female) from this database were selected for inclusion in this work based on rating responses provided by 24 undergraduate students in a pilot study (see Appendix B for the rating responses associated with these 16 models). This subset of the NimStim faces included European-American, Asian-American, Latino-American and African-American models. Four additional models from the NimStim face set (2 male; 2 female) were used as stimuli for practice trials. Each face was set into an oval template. Areas outside the oval and non-face features within the oval (for example, the neck, hair and shoulders) were replaced with a black background.

Throughout the experiments, the faces could be presented in central, parafoveal or peripheral locations. In a pilot study with 4 postgraduate students (see Appendix C), it was found that the expression (angry, happy or neutral) of a face could be determined with 97.73% (*SD* = 1.56) and 94.97% (*SD* = 2.73) accuracy in parafoveal and peripheral locations, respectively. This is important as it indicates that threatening (angry) and non-threatening (happy and neutral) faces could be recognised with a high level of accuracy at the eccentricities used in the reported experiments.

The experiments were created and implemented using Experiment Builder software (SR Research Ltd.) and presented on a 20 inch monitor (1280 x 1024 resolution). Although viewing was binocular, the vertical and horizontal movements of the right eye were sampled monocularly at a rate of 1000 Hz. The majority of the participants in Experiment 1 (n = 39, 74%) and Experiment 2 (n = 43, 72%) completed the tasks at a viewing distance of 57 cm using an Eyelink 1000 Tower Mount eye-tracking system (SR Research Ltd.). Due to a change in the equipment at the University of Southampton, 14 participants in Experiment 1, 17 participants in Experiment 2 and all participants in Experiment 3 and Experiment 4 completed the tasks at a viewing distance of 70 cm using an Eyelink 1000 Desk Mount eye tracking system (SR Research Ltd.).

In order to accommodate these equipment changes, the size of all display items (targets and distractors) and the distance between the display items, in pixels, was increased by 23% to ensure that they occupied the same horizontal and vertical visual angles and were presented at the same eccentricities at both viewing distances. The faces were 134 x 208 pixels in size (4.2° horizontally and 6.5° vertically) at a viewing distance of 57 cm and 165 x 256 pixels in size (4.2° horizontally and 6.5° vertically) at a viewing distance of 70 cm. Viewing distance (57 cm vs. 70 cm) did not have a significant effect on any of the dependent variables reported in Experiment 1 or Experiment 2 when the analyses were repeated with viewing distance entered as a covariate.

The Eyelink 1000 system is video-based and uses corneal reflection tracking in combination with pupil tracking. This system uses an on-line parser to identify and analyse the components of the eye movement data stream (e.g., saccades and fixations). It uses saccade detection methods that identify saccades based on velocity, acceleration and motion thresholds. A saccade signal is generated if the eye movement velocity exceeds 30°/second or if the eye movement acceleration exceeds 8000°/second^2. The motion threshold ensures that a saccade is only detected when the amplitude of the eye movement is greater than 0.1°.

3.2.3 Materials

Primarily, the empirical work presented throughout this thesis is concerned with the relationship between trait anxiety and threat processing as this is emphasised in the cognitive models of anxiety. However, Chapter 2 highlighted that there is evidence of a threat bias in trait anxious (Bradley et al., 1998; Byrne & Eysenck, 1995), state anxious (Mogg et al., 1997), socially anxious (Gilboa-Schechtman et al., 1999; Mogg & Bradley, 2002) and clinically anxious (Eastwood et al., 2005; MacLeod et al., 1986) individuals. Therefore, the existing empirical studies have provided no evidence to indicate that the threat bias is specific to a particular form of anxiety. In order to consider the specificity of the threat bias, the experiments reported in this thesis considered the effects of trait anxiety, state anxiety and social anxiety. In line with previous research, social anxiety was conceptualised as two distinct types of social fear: a fear of public scrutiny and negative evaluation and; fear and distress when interacting with other people (Mattick & Clarke, 1998). Participants completed the state and trait versions of the State-Trait Anxiety Inventory (Spielberger, 1983), the full version of the Fear of Negative Evaluation Scale (Watson & Friend, 1969) and the Social Interaction Anxiety Scale (Mattick & Clarke, 1998). It was not considered necessary to recruit clinical samples due to the dimensional nature of anxiety.

Participants also completed the Attentional Control Scale (Derryberry & Reed, 2002) due to the emphasis placed on impaired attentional control in recent cognitive models of anxiety (e.g., Eysenck et al., 2007; Fox et al., 2001, 2002),. In line with ACT (Eysenck et al., 2007), it was predicted that there would be an inverse relationship between anxiety and attentional control. It was further predicted that low levels of attentional control would have a negative effect on performance in each experiment (for threatening and non-threatening stimuli) due to an inability to focus attention on the task.

The State-Trait Anxiety Inventory is a self-report measure of state and trait anxiety. The state scale (STAI-S) consists of 20 items asking participants to rate how they feel 'at this moment' on a 4-point Likert response scale (ranging from 'not at all' to 'very much so'). The trait scale (STAI-T) consists of 20 items asking participants to rate how they 'generally feel' on a 4-point Likert response scale (ranging from 'almost never' to 'almost always'). The possible range of scores on each scale is 20-80. The STAI-S and STAI-T have good internal consistency with Cronbach's α values ranging from .91 to .93 (Endler, Cox, Parker, & Bagby, 1992).

The Fear of Negative Evaluation Scale (FNES) assesses the participant's expectation of being negatively evaluated, their apprehension about receiving negative evaluation, and their avoidance of being evaluated. Participants are asked to rate 30 statements as true or false. A total FNES score can range from 0-30. The FNES has good internal consistency (Kuder-Richardson 20 = .93 (Rodebaugh et al., 2004)).

The Social Interaction Anxiety Scale (SIAS) is a 19-item instrument that assesses the extent to which the participant feels distress when interacting (e.g. meeting or talking) with other people. Participants are asked to indicate on a 5-point response scale (ranging from ‘not at all’ to ‘extremely’) how much each statement is characteristic of them. The possible range of scores on this questionnaire is 0-76. This scale has good internal consistency (Cronbach’s α = .90 in a community sample (Mattick & Clarke, 1998)).

The Attentional Control Scale (ACS) consists of 20 items which the participant rates on a 4-point response scale (ranging from ‘almost never’ to ‘always’) according to how much they feel the statement is true of them. The ACS assesses two forms of attentional control: attentional focusing (e.g., ‘When I need to concentrate and solve a problem, I have trouble focusing my attention’) and attentional shifting (e.g., ‘I can easily switch from one task to another’). The internal consistency of the total score is acceptable (Cronbach’s α = .88; (Derryberry & Reed, 2002)). Total scores on this scale can range from 20-80.

See Appendix D for the full list of questions and the response scales for these self-report questionnaires.

3.2.4 Procedure

In each study, the order of presentation of the experimental blocks was counterbalanced across participants following a Latin Square design. The order of trials within each block was fully randomised for each participant. Eye movement recording began after the completion of practice trials. The recording phase started with a calibration and validation process; participants sequentially fixated 9 dots presented in a 3 x 3 array on the screen.

Participants completed the SIAS prior to the day of testing. On the day of testing, participants completed the STAI-S immediately prior to the eye tracking task and the STAI-S, STAI-T, FNES and ACS immediately following the eye tracking task (the only exceptions were that the STAI-S was not completed prior to the eye tracking task in Experiment 1 and the FNES was not completed in Experiment 2). Participants were fully debriefed after completing the questionnaires.

3.2.5 Data Preparation

Exclusion criteria. Data Viewer software (SR Research Ltd.) was used to view and prepare the data for analysis. Trials were removed from the data set if: 1) the fixation location at the beginning of the trial was more than one degree away from the centre of the screen; 2) an anticipatory eye movement occurred (defined as first saccades with latencies less than 80 ms (Wenban-Smith & Findlay, 1991)); 3) a blink occurred. First saccades were defined as the earliest saccade in a trial with amplitude greater than one degree; if the initial saccade was less than one degree, then it was removed and replaced by the subsequent saccade.

Participant characteristics. For purely descriptive purposes, the percentage of participants reporting ‘high’ levels of anxiety was calculated for each questionnaire measure in each experiment. There are no fixed clinical cut-off scores provided in the development of the self-report measures of anxiety used in this thesis. However, following conventions adopted in previous research (Heimberg, Mueller, Holt, Hope, & Liebowitz, 1992; Millar, Jelicic, Bonke, & Asbury, 1995), a cut-off was derived for each scale at one standard deviation above the mean. The mean and standard deviation used in these calculations were based on norms provided in the development of each scale from community samples. In a community sample of adults aged 19-39, Spielberger (1983) reported means on the STAI-T of 35.55 (*SD* = 9.76) for males and 36.15 (*SD* = 9.53) for females and means on the STAI-S of 36.54 (*SD* = 10.22) for males and 36.17 (*SD* = 10.96) for females. Therefore, the cut-off value derived for the STAI-T and STAI-S was 46 based on a mean of 36 and a standard deviation of 10. Mattick and Clarke (1998) reported a mean of 18.8 and a standard deviation of 11.8 in a community sample and, therefore, the cut-off value on this scale was 31. Finally, Watson and Friend (1969) reported a mean of 15.47 and a standard deviation of 8.62 in a sample of college students and, therefore, the cut-off value on this scale was 24.

3.2.6 Data Analysis

In each experiment, data analysis consisted of an analysis of the basic effects associated with the paradigm across participants and, more importantly, an analysis of the effects of anxiety and attentional control on task performance for threatening and non-threatening faces. The analysis of the basic effects was typically conducted using repeated measures analysis of variance (ANOVA). The effects of anxiety and attentional control were considered using multiple regression analyses. In all regression analyses, attentional control scores were the combined total from the attentional focusing and attentional shifting subscales.

The inclusion of all anxiety measures within the regression models raised the possibility of high mulitcollinearity. Multicollinearity between the predictors should be regarded as too high if correlations between the predictors have a coefficient greater than .80, if the Variance Inflation Factor (VIF) for any single predictor is greater than 10, if the average VIF across all predictors is substantially greater than 1 or if the tolerance statistic (1/VIF) is below .2 (Field, 2005). For all multiple regression analyses conducted throughout the empirical studies, the correlation coefficients between the predictors were less than .80, all of the predictors had a VIF value below 3.80 and an average VIF less than 2.33 and the tolerance statistics for each predictor were greater than .26. Therefore, the level of multicollinearity between the predictors was acceptable for these analyses to be conducted in all experiments.

Theoretical accounts of anxiety have raised the possibility that the attentional bias to threat in high trait anxious individuals is particularly apparent when there are also high levels of state anxiety (Eysenck, 1992; Mogg & Bradley, 1998) or low levels of attentional control (Lonigan et al., 2004). The current work made no attempt to manipulate state anxiety or to ensure that there were equivalent numbers of high trait anxious individuals with high and low levels of attentional control. However, exploratory correlational analyses were conducted to verify that the threat bias was consistent across individuals with high levels of anxiety rather than pertaining to a subsection of anxious individuals. Specifically, correlations were conducted between the dependent variables and the interaction terms for state anxiety x trait anxiety and for trait anxiety x attentional control. These interactions were not included in the regression analyses because they substantially increased the level of multicollinearity in the regression models. Exploratory correlations were also conducted to consider the associations between the dependent variables and the separate subscales of the ACS (i.e., attentional focusing and attentional shifting).

An item analysis was conducted in Experiment 1 and Experiment 2. For each of the 16 models, the dependent variables were calculated for each expression in every type of display. The basic analyses were repeated to assess the effects of the independent variables on the model means. The purpose of this analysis was to replicate the basic effects from the participant analysis, thereby confirming that the effects could not be attributed to any specific model(s).

Note that all statistical tests were two-tailed with an alpha level of .05.

3.3 Method for the Current Study

3.3.1 Participants

Fifty-three healthy adults participated in the experiment (*mean age* = 20.80 years, *SD* = 3.22, *range* = 18-33 years; 11 males).

3.3.2 Stimuli

The target and distractor stimuli used in this experiment were the 20 models described in Section 3.2.2 (i.e., consisting of 16 models for the experimental trials and four models for the practice trials). The visual search displays contained one target face (angry, happy or neutral) in an upright orientation set amongst one, three or seven distractor faces in an inverted orientation. Within each display, the distractors were identical to the target with the exception of the 180° rotation. The rationale for making the target and distractors identical was to eliminate low level feature differences between the display items (Cave & Batty, 2006). Eight-peripheral displays contained a circular array of eight faces; four of these were removed to create the four-peripheral displays; two-peripheral displays contained two faces positioned on the horizontal axis. Two-parafoveal displays were identical to two-peripheral displays with the exception of target eccentricity. When the viewing distance was 57 cm, the centre of each face was positioned at 144 pixels (4.5° eccentricity) from the centre of the display in the parafoveal condition, and at 288 pixels (9° eccentricity) from the centre of the display in the peripheral condition. When the viewing distance was 70 cm, the centre of the parafoveal and peripheral stimuli were presented at 177 pixels (4.5° eccentricity) and 354 pixels (9° eccentricity), respectively, from the centre of the screen. See Figure 3.1A for an example of each type of display.

3.3.3 Design

Within-subject factors were set size (8, 4, 2), eccentricity (parafoveal and peripheral) and target expression (angry, happy, and neutral). Between-subject factors were self-reported anxiety and attentional control.

The dependent variables were defined as follows: a) Percentage of accurate first saccades: accurate saccades were those that landed on or within one degree of the target; b) Latency of the accurate first saccades: the elapsed time between the onset of the visual search display and the initiation of the first saccade; c) Total time taken to locate the target: the elapsed time between the onset of the visual search display and the time at which the eye landed on the target; d) Success rate: the percentage of trials in which a saccade landed on or within 1 degree of the target, irrespective of how many saccades were executed in this process before the offset of the display; e) Gradient of the search slope (accuracy): search slopes were generated by regressing the percentage of accurate first saccades against set size for every participant and for each expression separately (using peripheral displays only); f) Gradient of the search slope (total time taken):

search slopes were generated by regressing the total time taken to locate the target against set size for every participant and for each expression separately (using peripheral displays only).

Figure 3.1 has been removed for copyright purposes

Figure 3.1. Example stimulus displays for each condition and an example of a trial sequence in the visual search task.

Note: (A) Examples of: (1) eight-peripheral displays; (2) four-peripheral displays; (3) two-peripheral displays; (4) two-parafoveal displays; (a) angry displays; (b) happy displays; (c) neutral displays. (B) An example of a trial sequence.

3.3.4 Procedure

Participants completed four blocks of trials, one block for each different set size for the peripheral displays and one block for the parafoveal displays. Each block contained 20 practice trials and 96 experimental trials. Within each block, there were an equal proportion of trials associated with each expression and the target appeared in every possible location with an equal frequency. Findlay and Walker (1999) distinguished between search selection (a tendency to execute saccades to a particular visual feature) and spatial selection (a tendency to execute saccades to a particular location) in Level 4 of their information processing model (see Figure 2.1). Therefore, the rationale for blocking by set size and eccentricity was to ensure that the region of space selected for search was constant within a block of trials (i.e. to minimise individual differences in spatial selection). Instead, the current study was primarily concerned with individual differences in search selection (e.g., a bias to execute saccades to angry faces in anxious individuals).

A trial began with a centrally-located white fixation cross, presented on a black background until the participant had fixated within one degree of the centre of the screen for 200 ms (the fixation cross was presented for a minimum duration of 1000 ms). A visual search display followed for 1000 ms. The inter-stimulus interval was 1000 ms. See Figure 3.1B for an example of the trial sequence. Participants were instructed to look at the upright face as quickly and as accurately as possible in every trial.

3.3.5 Data Preparation

Exclusion criteria. In addition to the general exclusion criteria outlined in Section 3.2.5, trials were removed if the accurate or inaccurate first saccade latency was more than 3 standard deviations away from the participant's mean accurate or inaccurate first saccade latency, respectively. Very long latency saccades are frequently discarded in eye movement studies because they are less likely to be elicited by the stimuli presented in the display and may, for example, reflect lapses in attention. Three participants were completely removed from the analysis because at least 2/3 of their trials had to be excluded from one or more experimental blocks. In the remaining 50 participants (*mean age* = 20.58 years, *SD* = 3.10, *range* = 18-33; 10 males), 8.67% of the trials were removed based on the exclusion criteria. Furthermore, the amplitude of the initial saccade was smaller than 1 degree in 4.2% of the trials; in these cases, the initial saccade was removed and replaced by the subsequent saccade.

Participant characteristics. The mean total scores and the internal consistency for each questionnaire are provided in Table 3.1. In the current sample, 14 participants (28%) scored 46 or more on the STAI-T, seven participants (14%) scored 46 or more on the STAI-S, 14 participants (28%) scored 31 or more on the SIAS and 14 participants (28%) scored 24 or more on the FNES.

The inter-correlations between the measures of individual differences and age are presented in Table 3.2. Note that Spearman's rank correlations were conducted with age due to the skewed distribution of this variable; Pearson's product moment correlations were conducted in all other cases because the scores on the questionnaire measures were normally distributed. As expected, the anxiety measures were positively correlated with one another and negatively correlated with attentional control.

Table 3.1. *Descriptive statistics and internal consistency for the questionnaire measures and age.*

	M	*SD*	*Minimum (lower limit)*	*Maximum (upper limit)*	*Cronbach's α*
Trait Anxiety (STAI-T)	39.66	10.22	20 (20)	62 (80)	.93
State Anxiety (STAI-S)	35.50	9.71	21 (20)	57 (80)	.93
Social Interaction Anxiety (SIAS)	23.32	13.56	0 (0)	57 (76)	.94
Fear of Negative Evaluation (FNES)	17.68	7.69	1 (0)	29 (30)	.92
Attentional Control (ACS)	51.10	7.73	33 (20)	68 (80)	.82
Age (in years)	20.58	3.10	18	33	*na*

Table 3.2. *Inter-correlations between self-reported anxiety and attentional control measures and age.*

	1	2	3	4	5	6 [a]
1. Trait Anxiety (STAI-T)	-	.61***	.63***	.63***	-.61***	.12
2. State Anxiety (STAI-S)		-	.37**	.39**	-.57***	.17
3. Social Interaction Anxiety (SIAS)			-	.64***	-. 50***	.20
4. Fear of Negative Evaluation (FNES)				-	-.40**	.23
5. Attentional Control (ACS)					-	.17
6. Age (in years) [a]						-

[a] A Spearman's r_s was calculated for this variable due to its skewed distribution (Pearson's *r* was calculated for all other variables).

*** $p < .001$, ** $p < .01$, * $p < .05$, $p < .10$

3.3.6 Data Analysis

The principal question of interest was whether individual differences in anxiety or attentional control were associated with enhanced search efficiency and enhanced localisation for threatening (and not non-threatening) faces. Multiple regression analyses were conducted to consider the effects of anxiety and attentional control on search performance. The forced entry method was used for each multiple regression; that is, the five predictors (trait anxiety, state anxiety, social interaction anxiety, fear of negative evaluation and attentional control) were entered into the regression model simultaneously. This was an appropriate regression method because, while there were good theoretical reasons for including the five predictors, there was no rationale for assigning greater importance to one predictor over another. Furthermore, exploratory correlations were conducted between the dependent variables and the interaction term for state anxiety x trait anxiety, the interaction term for trait anxiety x attentional control and the separate attentional focusing and attentional shifting subscales of the ACS.

There were three stages of data analysis, which corresponded to the three aims of the study. Analyses explored whether anxiety was associated with: 1) enhanced localisation of peripheral threat as indexed by the speed and accuracy of directing the eyes towards a peripheral angry face and; 2) enhanced search efficiency for angry faces as assessed by search slope gradients. In addition, it assessed whether enhanced localisation of threat in anxiety was more evident in parafoveal displays as indexed by the speed and accuracy of directing the eyes towards a parafoveal angry face.

In addition to considering the effects of anxiety on search performance, it was important to test for the basic effects associated with the visual search paradigm. Repeated measures ANOVAs were conducted to establish whether the dependent variables were influenced by set size, target eccentricity or target expression across participants. The effect of set size was only considered in peripheral displays and the effect of eccentricity was only considered in displays containing two items because it would have been necessary to considerably reduce the size of the faces in order to construct parafoveal displays with four or eight display items.

3.4 Results

3.4.1 Target Localisation in Peripheral Displays

This analysis focused on the speed and accuracy of locating threatening and non-threatening faces across participants and, critically, as a function of anxiety and attentional control.

Basic effects. Two-way repeated measures ANOVAs were conducted to assess the basic effects associated with the paradigm for the percentage of accurate first saccades and the total time taken to locate the target. Set size (eight-peripheral, four-peripheral, two-peripheral) and expression (angry, happy, neutral) were entered as within-subject variables in each ANOVA. Figure 3.2 shows the percentage of accurate first saccades and the total time taken to locate the target for each expression and each set size. Note that it was not appropriate to consider the effect of set size on accurate first saccade latencies because the first saccade accuracy was at chance levels for a number of the participants on the eight-peripheral and four-peripheral displays. In addition, it was not appropriate to consider the effect of set size on success rate because performance in the four-peripheral and two-peripheral displays was close to ceiling levels across participants on this dependent variable (four-peripheral: $M = 95.63\%$, $SD = 4.17\%$; two-peripheral: $M = 98.99\%$, $SD = 0.68\%$).

Main effects were observed for set size on the percentage of accurate first saccades, $F(2, 98) = 368.85$, $p < .001$ and the total time taken to locate the target, $F(2, 98) = 335.18$, $p < .001$. Table 3.3 shows the means for each set size. Accuracy of the first saccades decreased as set size increased and the total time taken to locate the target increased as set size increased (all pairwise comparisons were highly significant, $ps < .001$, $ds > 1$). This indicates that search performance deteriorated with increasing set size and that search for faces was carried out using inefficient search processes.

There was a significant main effect of expression on the percentage of accurate first saccades, $F(1.69, 82.57) = 6.26$, $p < .01$ and the total time taken to locate the target, $F(2, 98) = 20.21$, $p < .001$. Pairwise comparisons revealed that: a) the percentage of accurate first saccades was significantly greater for angry faces compared with neutral faces ($p < .01$, $d = 0.27$) and; b) participants were significantly faster to locate angry faces compared with neutral faces ($p < .001$, $d = 0.56$), significantly faster to locate angry faces compared with happy faces ($p < .01$, $d = 0.26$) and significantly faster to locate happy faces compared with neutral faces ($p < .01$, $d = 0.29$). As outlined above, the success rate was not considered in displays containing four or two items. However, a one-way ANOVA was conducted on eight-peripheral displays with expression entered as a within-subject variable. There was a main effect of expression on the success rate in eight-peripheral displays, $F(2, 98) = 12.03$, $p < .001$. This was due to a higher overall success rate for angry faces compared with neutral faces ($p < .001$, $d = 0.58$) and happy faces ($p < .01$, $d = 0.48$). Thus, angry faces were located with greater speed and accuracy compared with neutral faces and happy faces (although note that the percentage of accurate first saccades did not differ significantly for angry and happy targets). Furthermore, happy faces were located with greater speed than neutral faces. Table 3.4 presents the means for each expression.

There were no significant interactions between expression and set size on the percentage of accurate first saccades or the total time taken to locate the target (all *Fs* < 1.5, *ns*). This suggests that the effect of set size was consistent across all expressions and indicates that search efficiency was unaffected by the expression of the face.

Anxiety. For each expression (collapsed across the peripheral set sizes), the percentage of accurate first saccades and the total time taken to locate the target in peripheral displays were regressed against the five predictors (trait anxiety, state anxiety, social interaction anxiety, fear of negative evaluation and attentional control). This analysis allowed a consideration of whether there was an overall effect of anxiety or attentional control on search performance; for example, it was predicted that anxiety would be associated with increased speed and accuracy in searching for angry faces, irrespective of set size. There were no significant regression models for any expression on either dependent variable, R^2s < .11, *F*s < 1, *ns,* and there were no significant predictors within the models, $|\beta s| < .32$, *p*s > .10. This indicates that neither anxiety nor attentional control predicted the speed or accuracy of localising peripheral target faces, irrespective of expression. Spearman's correlations between the interaction terms (trait anxiety x state anxiety and trait anxiety x attentional control) and the dependent variables were non-significant for each expression, *ps* > .10, *ns*, indicating that it is unlikely that enhanced localisation of threatening (or non-threatening) faces occurred in the specific subsections of high trait anxious individuals who were high in state anxiety or low in attentional control. Pearson's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the dependent variables were also non significant for each expression, *ps* > .10, *ns*.

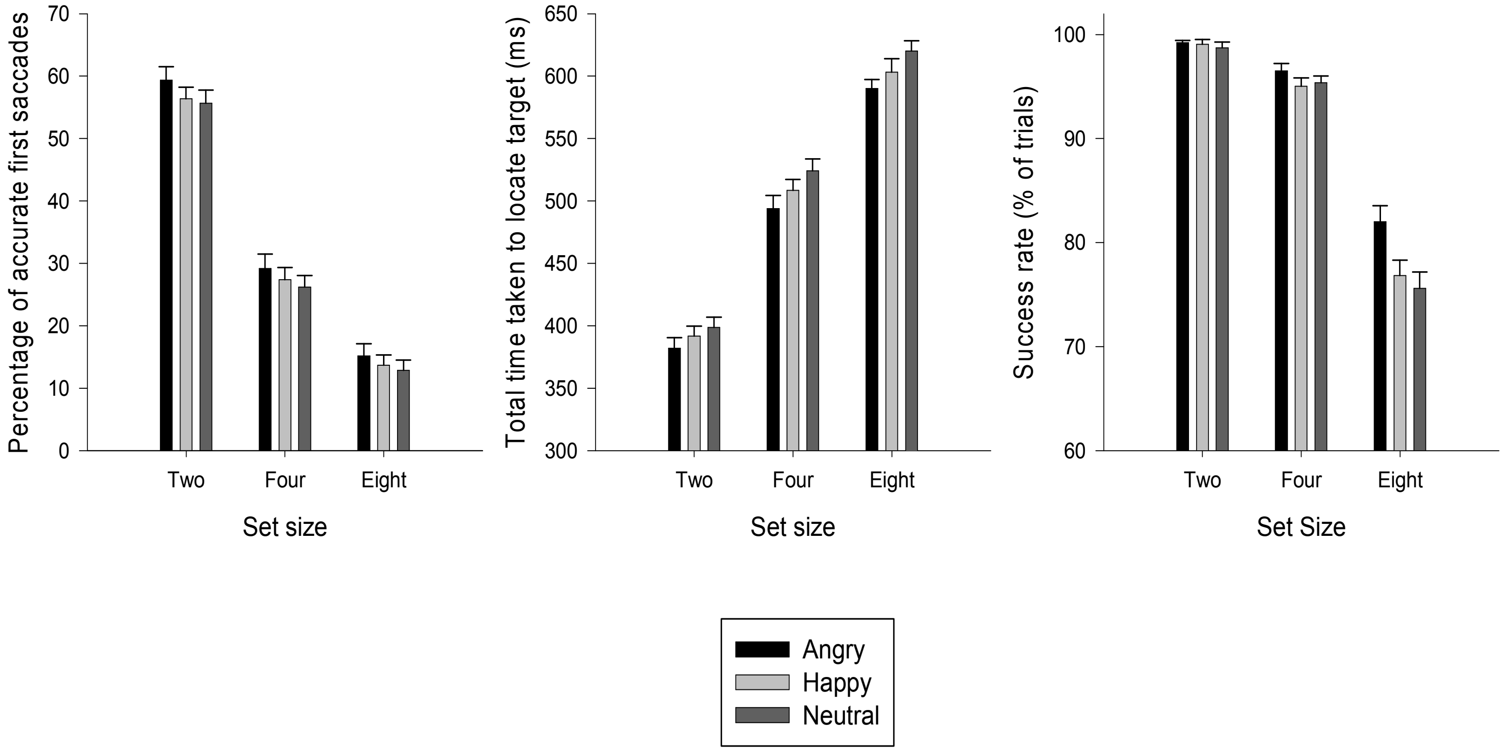

Figure 3.2. Mean (+*SE*) for the percentage of accurate first saccades (left), the total time taken to locate the target (middle) and the success rate (right) as a function of target expression and set size.

Table 3.3. *Summary of the mean (+SD) for the percentage of accurate first saccades and the total time taken to locate the target as a function of set size (collapsed across expressions and based on peripheral displays only).*

	Eight-peripheral[a]		Four-peripheral[b]		Two- peripheral[c]		
	M	*SD*	*M*	*SD*	*M*	*SD*	*p*[*]
Percentage of accurate first saccades	13.92	11.03	27.59	13.01	57.14	12.73	<.001[abc]
Time taken to locate target (in ms)	604.61	48.51	508.95	61.09	390.84	54.59	<.001[abc]

[*] *p*-values to indicate statistically significant pairwise comparisons, [abc] represents a significant difference between every pair of set sizes.

Table 3.4. *Summary of the mean (+SD) for the percentage of accurate first saccades, total time taken to locate the target, success rate and search slope gradients as a function of target expression (collapsed across set size and based on peripheral displays only).*

	Angry faces[a]		Happy faces[b]		Neutral faces[c]		
	M	*SD*	*M*	*SD*	*M*	*SD*	*p*[**]
Percentage of accurate first saccades	34.57	12.30	32.50	10.11	31.57	10.18	<.01[ac]
Total time taken to locate the target (in ms)	488.78	48.65	501.22	47.59	514.41	42.78	<.01[abc]
Success rate (%)*	82.00	11.03	76.84	10.39	75.59	11.10	<.01[ac,ab]
Gradient of the search slope (%/item)	-6.81	2.47	-6.59	2.33	-6.59	2.40	*ns*
Gradient of the search slope (ms/item)	33.17	10.04	33.62	12.80	35.08	13.44	*ns*

*Based on eight-peripheral displays only. ** *p*-values to indicate statistically significant pairwise comparisons, [ac] represents a significant difference between angry and neutral faces, [ab] represents a significant difference between angry and happy faces, [abc] represents a significant difference between every pair of expressions.

3.4.2 Search Efficiency in Peripheral Displays

This analysis focused on the relationship between the measures of individual differences and the speed and accuracy of locating a target face as a function of set size. Specifically, the gradient of the slope of the line was calculated for the percentage of accurate first saccades and the total time taken to locate the target by regressing these variables against set size for each expression separately. It was unnecessary to consider the effect of expression on search slopes across participants (i.e. the basic effect) in this analysis because the non-significant interactions between set size and expression in the preceding ANOVAs indicated that the effect of set size was consistent across expressions. Descriptive statistics for the gradients of the search slopes are presented in Table 3.4.

For each expression separately, the search slopes for the percentage of accurate first saccades and the total time taken to locate the target were regressed against the five anxiety and attentional control predictors. There were no significant regression models for any expression on either dependent variable, R^2s < .06, *F*s < 1, *ns,* and there were no significant predictors within the models, $|\beta s|$ < .27, *p*s > .10. Thus, neither anxiety nor attentional control predicted search efficiency for any expression. Spearman's correlations between the interaction terms (trait anxiety x state anxiety and trait anxiety x attentional control) and the dependent variables were non-significant for each expression, *ps* > .10, *ns*; thus, there was no evidence to indicate that enhanced efficiency in searching for threat occurred in the subsection of high trait anxious individuals who were high in state anxiety or low in attentional control. Pearson's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the dependent variables were also non significant for each expression, *ps* > .10, *ns*.

3.4.3 Eccentricity and Target Localisation

This analysis considered the speed and accuracy of locating threatening and non-threatening faces as a function of target eccentricity across participants. It also considered whether anxiety or attentional control affected the speed and accuracy of locating target faces in parafoveal displays.

Basic effects. Repeated measures ANOVAs were conducted with eccentricity (two-peripheral, two-parafoveal) and expression as within-subject variables. Figure 3.3 shows the percentage of accurate first saccades and the latency of the accurate first saccades as a function of expression and eccentricity. The time taken to locate the target and the success rate were not included as dependent variables in the eccentricity analysis because the first saccade measures are the only dependent variables that elicit meaningful variation in a comparison of displays containing only two items. For two-parafoveal displays, the success rate was greater than 97% for all target expressions and the mean time taken to locate the target was 336.86 ms (*SD* = 48.47), 336.50 ms (*SD* = 53.53) and 344.81 ms (*SD* = 57.27) for angry, happy and neutral faces, respectively.

There was a significant effect of eccentricity, $F(1, 49) = 20.53$, $p < .001$, $d = 0.61$, on first saccade accuracy in which the percentage of accurate first saccades in two-parafoveal displays ($M = 63.79$, $SD = 8.70$) was significantly greater compared with two-peripheral displays ($M = 57.14$, $SD = 12.73$). There was a marginal effect of eccentricity on the latency of the accurate first saccades, $F(1, 49) = 3.24$, $p = .078$, $d = 0.19$, where the latency of the accurate first saccades in the two-parafoveal displays ($M = 225.21$, $SD = 57.49$) was shorter compared with the two-peripheral displays ($M = 237.53$, $SD = 73.61$). Therefore, the accuracy of the first saccades increased and the latency of the accurate first saccades decreased as target eccentricity decreased.

There was a trend towards an effect of expression on first saccade accuracy, $F(2, 98) = 3.02$, $p = .053$, which could be explained by a higher percentage of accurate first saccades to angry faces ($M = 62.02$, $SD = 11.95$) compared with neutral faces ($M = 59.11$, $SD = 10.32$, $p = .081$, $d = 0.26$). In accordance with the previous expression findings, the percentage of accurate first saccades for happy faces ($M = 60.26$, $SD = 9.90$) did not differ from angry or neutral faces. There was neither an effect of expression on the latency of accurate first saccades (Angry: $M = 230.77$ ms, $SD = 63.14$; Happy: $M = 231.19$ ms, $SD = 59.75$; Neutral: $M = 232.16$ ms, $SD = 62.79$) nor an interaction between eccentricity and expression for the percentage of accurate first saccades or the latency of accurate first saccades (all *Fs* < 1, *ns*).

Anxiety. The percentage of accurate first saccades in two-parafoveal displays and the latency of the accurate first saccades in two-parafoveal displays were regressed against the five anxiety and attentional control predictors. There were no significant regression models for any expression on either dependent variable, R^2s < .09, *F*s < 1, *ns,* and there were no significant predictors within the models, $|\beta s| < .32$, *p*s > .10. This indicates that neither anxiety nor attentional control predicted the speed or accuracy of localising parafoveal target faces, irrespective of expression. Spearman's correlations between the interaction terms (trait anxiety x state anxiety and trait anxiety x attentional control) and the dependent variables were non-significant for each expression, *ps* > .10, *ns*. Pearson's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the dependent variables were also non significant for each expression, *ps* > .10, *ns*.

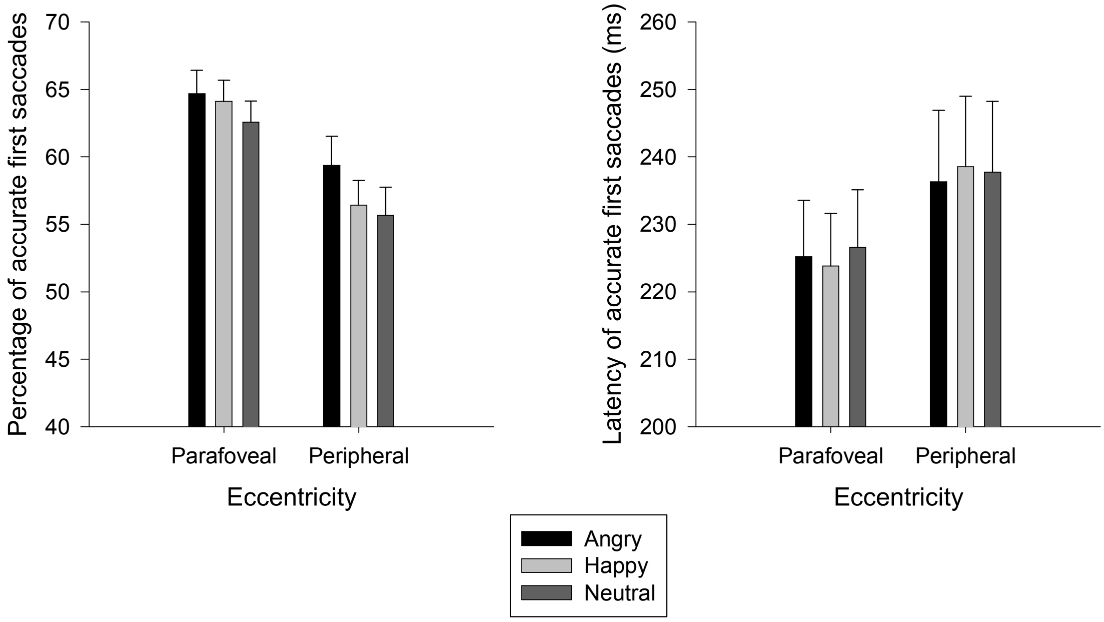

Figure 3.3. Mean (+ *SE)* for the percentage of accurate first saccades (left) and the latency of accurate first saccades (right) as a function of target expression and eccentricity (for displays containing two items).

3.4.4 Item Analysis

All of the above ANOVAs were repeated on the model means rather than the participant means. All of the significant effects involving set size, eccentricity and expression found in the preceding analyses were replicated in the item analysis. Therefore, these significant effects cannot be attributed to individual models.

3.5 Discussion

The present study aimed to establish whether anxiety is associated with enhanced localisation of threat. Specifically, it considered whether individuals with high levels of anxiety were quicker, more accurate and more efficient when searching for threatening (but not non-threatening) faces in parafoveal and peripheral regions of the visual field.

The current study found that there was a bias in orienting towards angry faces in all individuals; angry faces were located with greater speed and accuracy compared with neutral and happy faces. This is consistent with previous target detection research reporting a search advantage for angry faces in studies measuring RTs (Fox et al., 2000;

Horstmann & Bauland, 2006; Öhman, Lundqvist, & Esteves, 2001) and eye movements (Reynolds et al., 2009). Thus, it could be argued that there was a selective attentional bias towards angry faces across participants. Despite this bias, it is important to note that angry faces were not consistently located with the initial orienting response and, furthermore, the speed and accuracy of locating an angry face decreased as search demands increased (i.e., as set size or eccentricity increased). That is, the localisation of angry faces occurred after an inefficient search. A potential limitation in the study is that this effect of expression might be driven by crowd effects. For example, if inverted angry faces were less distracting than inverted happy faces, then it is plausible that an angry target would be easier to locate than a happy target. However, this interpretation is deemed unlikely given that recent findings suggest that inversion disrupts emotion recognition to a similar extent across all intense facial expressions (Bould & Morris, 2008).

Contrary to predictions, this study provided no evidence to suggest that the initial orienting response (i.e. the first eye movement) or subsequent eye movements to angry faces were affected by anxiety. These findings are inconsistent with previous visual search studies measuring RTs, which indicate that anxiety is associated with greater speed and accuracy in detecting the presence of angry faces (Byrne & Eysenck, 1995; Matsumoto, 2010). Interestingly, a recent study found that anxiety was not associated with facilitated orienting towards threatening faces (Derakshan & Koster, 2010); a finding that is consistent with the results of the current study. Taken together, findings from the current localisation task and from eye movement measures during a detection task (Derakshan & Koster, 2010) concur in suggesting that anxiety is not linked to rapid orienting to threat.

It was predicted that anxiety would be associated with shallower search slopes for threatening (but not non-threatening faces) because the selective attentional bias to threat would allow anxious individuals to efficiently locate angry faces regardless of the complexity of the visual environment (i.e. the number of distractors). Contrary to this prediction, anxiety was not linked to shallower search slopes for angry faces; an inefficient search occurred in anxious and non-anxious individuals for all expressions. Thus, following previous eye tracking research (Brown et al., 1997; Calvo et al., 2008) and RT research (Fox et al., 2000), the present study found that searching for neutral or emotional faces was an inefficient process across all participants. Here, the accuracy of the first saccades decreased and the total time taken to locate the target increased as set size increased, indicating that participants located peripheral targets through multiple overt shifts in attention. In contrast with Reynolds et al., (2009), there was no evidence to suggest that the search advantage for angry faces increased as set size increased; the gradients of the search slopes were unaffected by the expression of the target face. One possible explanation for the discrepancy in results between the current study and those provided by Reynolds et al. (2009) is that the former explicitly required localisation of targets and the latter concurrently measured eye movements during a detection task. Given that localisation and detection require distinct attentional processes, it is perhaps unsurprising that differences in orienting responses occurred between the studies.

The current study also predicted that enhanced localisation of threat would be particularly apparent in parafoveal locations because it should be possible to extract threatening information of greater quality and quantity due to increased visual acuity in these regions of the visual field. The results from the eccentricity analysis provided no evidence to suggest that an anxiety-related bias in localising threat occurred in parafoveal regions. However, in line with previous research (Carrasco et al., 1998), the accuracy of the first saccade increased as retinal eccentricity decreased across participants. Despite enhanced performance with decreasing eccentricity, the results suggested that it was not possible to consistently locate the target with the first eye movement in parafoveal regions of the retina in displays containing only two items.

The accuracy of the first saccade for the two-peripheral (57.79%) and two-parafoveal (64.29%) displays was considerably lower than reported in previous studies using two stimuli (Crouzet, Kirchner, & Thorpe, 2010; Kirchner & Thorpe, 2006). Kirchner and Thorpe (2006) found that 90.1% of first saccades were accurate when participants were presented with two natural scenes for 20 ms and asked to make a saccade as quickly as possible to the side containing an animal. Similarly, Crouzet et al., (2010) found that 94.5% of first saccades were accurate when participants were presented with two natural scenes for 400 ms and asked to make a saccade as quickly as possible to the side containing a face. A plausible explanation for the discrepancy in these accuracy levels is that target-distractor similarity, which is known to increase search difficulty (Duncan & Humphreys, 1989), was considerably greater in the current study compared with the studies conducted by Kirchner and Thorpe (2006) and Crouzet et al (2010).

In addition to considering anxiety, the current study assessed the effects of attentional control. It was predicted that attentional control would be inversely associated with anxiety and positively associated with performance in the visual search task. That is, low levels of attentional control should be linked to elevated anxiety and decreased efficiency in locating threatening and non-threatening faces in parafoveal and peripheral regions of the visual field. There was evidence to suggest that high levels of anxiety were associated with low levels of attentional control. However, there was no evidence to support the hypothesis that low levels of attentional control lead to poor performance on the visual search task. It could be argued that this visual search task did not require attentional control because it was not necessary to regulate orienting responses; deficits in performance may be more evident in individuals reporting low levels of attentional control in tasks that require the suppression of exogenous saccades to task-irrelevant stimuli in order to execute endogenous saccades to task-relevant stimuli.

In summary, the current study provided no evidence to indicate that anxiety is associated with a greater ability to direct the spotlight of attention towards threat. Anxious individuals were neither faster nor more accurate in selectively focusing attention on a threatening stimulus such that it received processing priority while other non-threatening stimuli were ignored. This finding lies in stark contrast to the notion of selective attention to threat in anxious individuals (Mogg & Bradley, 1998; Williams et al., 1997). One possible reason for finding no evidence of enhanced localisation of threat is that anxiety may be characterised by an inability to regulate orienting responses, rather than an enhanced ability to generate orienting responses, in the presence of threat. It is possible that selective attention to threat only occurs when anxious individuals are required to use goal-directed attentional mechanisms to inhibit orienting responses to task-irrelevant threat such that they can focus attention on ongoing neutral tasks. This hypothesis is addressed in the next experiment.

Chapter 4 : Anxiety and Distraction from Threatening and Non-Threatening Faces

4.1 Introduction

The previous experiment found no evidence to indicate that anxiety was associated with selective attention to threat and performance enhancement in a task that involved responding to threatening stimuli (Eysenck et al., 2007). However, it remained possible that anxiety would be characterised by an inability to regulate orienting responses to threatening stimuli when they are task-irrelevant and disruptive to ongoing task performance. It might be that individuals with high levels of anxiety are unable to prevent the spotlight of attention shifting to task-irrelevant threat (i.e. attentional capture) or that they are unable to disengage the spotlight of attention from task-irrelevant threat. That is, selective attention to threat may only occur in anxiety when the stimulus-driven and goal-directed attentional systems are placed in direct competition (see Eysenck et al., 2007) and where task-irrelevant threat stimuli and task-relevant neutral stimuli compete for attentional resources.

The current study used the remote distractor paradigm to consider the effect of anxiety on the ability to use the goal-directed attentional system to regulate orienting responses in the presence of task-irrelevant threatening distractors. It explored the extent to which threatening distractors capture attention and interfere with ongoing processing. Resisting distractor interference is a top-down inhibitory process which involves suppressing distracting information and/or enhancing target information (Friedman & Miyake, 2004) and, therefore, it is of direct relevance to theories of anxiety which suggest that anxiety is characterised by impaired attentional control (Eysenck et al., 2007).

4.1.1 The Remote Distractor Paradigm

The remote distractor paradigm has been used to consider how task-irrelevant stimuli affect the oculomotor system as a function of their eccentricity and their position in relation to the target (Benson, 2008b; Gilchrist, Brown, Findlay, & Clarke, 1998; Walker, Deubel, Schneider, & Findlay, 1997). Walker et al (1997) gave participants a top-down goal to execute a saccade to a target (a cross) as quickly as possible. They were instructed to ignore the single distractor (a circle), which was presented on the majority of the trials. The distractor appeared simultaneously with the target and was presented at central fixation or in the ipsilateral or contralateral hemifield to the target.

Walker et al's., (1997) results indicated that, when the target and distractor appeared on the horizontal axis, a centrally presented distractor delayed the latency of the saccade to the target by 30-40 ms and a distractor presented in the contralateral hemifield led to an increase in saccade latency of 10-30 ms (compared with trials in which no distractor was presented). The latency of the saccades was unaffected by the presence of an ipsilateral distractor. There was a monotonic increase in saccade latency as the eccentricity of the distractor decreased. They also found that the amplitude of the saccade was only affected if the distractor was presented in the ipsilateral hemifield and, in these instances, the saccade landed between the target and distractor. More specifically, after presenting the target on the horizontal axis and the distractor on a variety of 2D axes, they found that the latency of the saccade increased when single distractors were presented in all locations with the exception of ipsilateral distractors presented within a region of ±20° around the target (the opposite pattern of results occurred with respect to saccade amplitude). They concluded that remote distractors affect the latency, but not the amplitude, of saccades. Neighbouring distractors affect the amplitude, but not the latency, of saccades.

These findings suggest that remote distractors capture attention in an involuntary and stimulus-driven manner and this cannot be overridden by the top-down attentional goals of the participant. The remote distractor effect (RDE) is the delay in saccade latencies to the target in response to the addition of a remote distractor. The RDE is at its largest magnitude when the distractor is presented simultaneously with a target or within 50 ms after the target (Buonocore & McIntosh, 2008; Walker, Kentridge, & Findlay, 1995) and it has been argued that it is an automatic or low-level phenomenon that occurs even when the location of the target is known in advance (Benson, 2008a; Walker et al., 1995). Furthermore, directional errors occur on approximately 10-30% of the trials in this paradigm (i.e., exogenous saccades directed towards the distractor instead of the target; Benson, 2008b).

Thus far, the remote distractor paradigm has not been employed to consider the threat-related bias in anxiety. However, recent research has considered whether initial eye movements are differentially affected by meaningful and non-meaningful remote distractors (Benson, 2008b). Benson (2008b) used the remote distractor paradigm to consider the effect of lexical and non-lexical distractors. In Experiment 3, the target was a cross (+) and the distractors were words, orthographically illegal letter strings or non-lexical shapes. The results indicated that saccade onset latencies to the target were slower in trials containing a lexical distractor (words or orthographically illegal letter strings) compared with a non-lexical distractor at all distractor locations (central, parafoveal and peripheral). At parafoveal locations, the saccade onset latencies to the target were slower in trials containing words compared with orthographically illegal letter strings. These findings suggest that participants found it more difficult to inhibit the processing of meaningful (vs. non-meaningful stimuli) and, consequently, this delayed the initiation of an endogenous saccade to the target. Indeed, Benson (2008b) concluded that the saccade generating system was affected by the lexical status of the distractor. Given that meaningful distractors lead to greater interference in comparison with non-meaningful distractors, it seems plausible that threatening distractors should be particularly meaningful and should interfere with ongoing performance to a greater extent for anxious (vs. non-anxious) individuals.

4.1.2 The Current Study

The current study tested the prediction that anxiety is associated with an inability to regulate orienting responses in the presence of threatening distractors (i.e., impaired inhibition of threat). It utilised a modified version of the original remote distractor task in which the target was a neutral stimulus (a white square or a white diamond) and the distractor was a threatening or non-threatening face.

An important advantage in using this paradigm was that the distractor and target were always presented in spatially distinct locations and, therefore, the distractor could be regarded as entirely task-irrelevant. In contrast, previous studies which have reported evidence of an inability to inhibit threat in anxiety have employed paradigms in which the threatening stimulus was either spatially coincident with the target (i.e. Stroop, Mogg et al., 2000) or in which the threatening stimulus served as a cue to the target location (e.g., the antisaccade paradigm; Derakshan et al., 2009). These studies required participants to inhibit processing of one attribute of the stimulus (e.g., the threatening meaning) and process another attribute of the same stimulus (e.g., the colour of the stimulus in the Stroop paradigm or the location of the stimulus in the antisaccade paradigm) in order to generate the necessary response. In this respect, the goal-directed and stimulus-driven attentional systems were not clearly delineated in these studies because it was not possible to completely suppress or ignore the threatening stimulus in order to enhance processing of the task-relevant component of the task. In the remote distractor paradigm, the target and task-irrelevant threat were attributes of different stimuli and, therefore, it was possible to inhibit the threatening distractor without detrimental effects to ongoing performance. In relation to eye movements and the

Competitive Integration Model of saccade generation (Godijn & Theeuwes, 2002, 2003), the separation of the target and distractor ensured that endogenous and exogenous saccades wee programmed to different locations in the visual field. Therefore, it was possible to consider whether anxious individuals were able to inhibit exogenous saccades to the location of a threatening distractor in order to execute an endogenous saccade to the location of a task-relevant neutral target.

Primarily, the current study aimed to elucidate the specific attentional processes that underlie the relationship between anxiety and distraction from threat. By manipulating the eccentricity of the distractor (i.e., central, parafoveal or peripheral), it was possible to generate a series of predictions related to these different attentional processes. Firstly, if individuals with high levels of anxiety involuntarily shift the spotlight of attention to task-irrelevant threatening stimuli in preference to task-relevant neutral stimuli, then anxiety would be associated with frequent and rapid saccades (i.e., directional errors) towards threatening distractors located in parafoveal and peripheral regions of the visual field. Secondly, if individuals with high levels of anxiety find it difficult to disengage the spotlight of attention from threat, then anxiety would be associated with a delay in moving the eyes away from central threatening distractors. Thirdly, this paradigm allowed an exploration of the possibility that anxiety is characterised by a broad focus of attention rather than a selective attentional bias to threat. In this case, an inability to regulate orienting responses would manifest itself as a delay in moving the eyes and the spotlight of attention to the task-relevant target when task-irrelevant threatening distractors are presented in central, parafoveal or peripheral locations.

In order to provide a direct comparison with previous RT (Fox, 1993, 1994, 1996; Georgiou et al., 2005) and anti-saccade research (Derakshan et al., 2009), a secondary aim of the study was to assess the relationship between anxiety and distractor interference in the context of a manual response task measuring RTs. Participants were asked to discriminate the target and indicate whether it was a square or a diamond. Previous RT studies (Fox, 1996; Georgiou et al., 2005) indicate that anxious individuals only demonstrate impaired inhibition of task-irrelevant threat that is presented within focal vision (i.e. central locations). However, predictions for the RT data were identical to the eye movement predictions in the current study.

4.2 Method

4.2.1 Participants

Sixty healthy adults participated in the experiment (*mean age* = 18.52 years, *SD* = 1.94, *range* = 16-27 years; 8 males).

4.2.2 Stimuli

The distractor stimuli used in this experiment were the 20 models described in Section 3.2.2 (i.e., 16 models for the experimental trials and four models for the practice trials). The target stimuli were a white square and a white diamond. The square and diamond were identical with the exception of a 45 degree rotation. Target stimuli were presented against a black background and were 48 x 48 pixels in size (1.5° x 1.5° of visual angle) at a viewing distance of 57 cm and 59 x 59 pixels in size (1.5° x 1.5° of visual angle) at a viewing distance of 70 cm.

The displays contained one target stimulus which was either presented on its own (single target trials) or with a task-irrelevant distractor (distractor trials). In the single target trials, the target was either presented at a parafoveal or peripheral location on the right or left of central fixation, corresponding to 128 pixels (4° eccentricity) or 256 pixels (8° eccentricity) respectively at a viewing distance of 57 cm. In the distractor trials, the distractor (angry, happy or neutral) could either appear in a central location (0° eccentricity), a parafoveal location (128 pixels; 4° eccentricity), or a peripheral location (256 pixels; 8° eccentricity) at a viewing distance of 57 cm. The centre of the parafoveal and peripheral stimuli (targets and distractors) were presented at 157.5 pixels (4° eccentricity) and 315 pixels (8° eccentricity) respectively from the centre of the screen at a viewing distance of 70 cm. Targets could appear at 4° or 8° eccentricity in trials containing central distractors. The target was always presented at 4° eccentricity in the contralateral hemifield to the parafoveal distractors and at 8° eccentricity in the contralateral hemifield to the peripheral distractors. See Figure 4.1A and 4.1B for an example of each type of display.

4.2.3 Design

Within-subject variables were trial type (single target trial, distractor trial), distractor eccentricity (central, parafoveal, peripheral) and distractor expression (angry, happy, neutral). Between-subject variables were self-reported anxiety and attentional control.

The dependent variables were defined as follows: a) Percentage of directional errors: errors were inaccurate first saccades that were directed towards parafoveal or peripheral distractor faces with an amplitude greater than two degrees; b) Latency of accurate first saccades: the elapsed time between the onset of the display and the initiation of the first saccade, where accurate first saccades were those directed towards the target with an amplitude greater than two degrees (note that first saccades, as defined in this experiment and whether accurate or inaccurate, occurred in at least 98.5% of the trials[1]); c) The reciprocal of the RTs to discriminate the target: the RT was the elapsed time between the onset of the display and the time at which the participant made the keypress response (for correct responses only; note that the reciprocal of the RTs was used to reduce the influence of outlier response times (Ratcliff, 1993)).

[1] The definition of accurate saccades and errors meant that a small proportion of the first saccades were neither categorised as accurate nor as errors. Specifically, this applied to: 1) 0.61% of the single target trials and 1.16% of the central distractor trials in which the first saccade was either directed towards the target with an amplitude less than 2° or was directed away from the target and; 2) 1.26% of the parafoveal distractor trials and 0.39% of the peripheral distractor trials in which the amplitude of the first saccade was less than 2°, regardless of whether it was directed towards or away from the target. The rationale for using 2° amplitude as a cut off was that the horizontal visual angle of a face was 4.2°. Therefore, only amplitudes greater than 2° could be regarded as accurate on central distractor trials. For consistency, the same criteria were maintained in the single target, parafoveal distractor and peripheral distractor trials. Statistical tests were not carried out on these unclassified first saccades because there were less than 1% differences across conditions and, furthermore, there were very few trials in which an unclassified first saccade occurred.

Figure 4.1 has been removed for copyright purposes

Figure 4.1. Example stimulus displays for each condition and an example of a trial sequence in the remote distractor task.

Note: (A) An example of a single target display (B) Examples of the distractor trials: (1) central distractor; (2) parafoveal distractor at 4° eccentricity; (3) peripheral distractor at 8° eccentricity; (a) angry distractor; (b) happy distractor; (c) neutral distractor. (C) An example of one trial sequence.

4.2.4 Procedure

Participants completed a practice block of 24 single target trials, followed by an experimental block of 48 single target trials (the block of single target trials served as a measure of baseline performance). Participants were instructed to look at the target as quickly and accurately as possible and to make a key-press response to indicate whether the target was a square or a diamond.

Participants then completed a practice block of 24 distractor trials (i.e., with the faces), as well as three experimental blocks (one for each distractor expression) containing 48 single target trials and 96 distractor trials (32 central distractor trials, 32 parafoveal distractor trials and 32 peripheral distractor trials). In this phase of the experiment, participants were instructed to look at the target as quickly and accurately as possible and to make a key-press response to indicate whether the target was a square or a diamond; they were informed that a face would appear on some of the trials and that they should ignore it. Previous research indicates that processing of the distractor can carryover from distractor trials to single target trials within the same block (Benson, 2008b). Therefore, the rationale for blocking by expression was to ensure that any carryover effects were attributable to only one type of emotional distractor within a block of trials.

For every condition, half of the trials contained a target square and the other half contained a target diamond. Both targets (square and diamond) appeared in each of the four possible target locations with an equal frequency (i.e. 4° or 8° to the right or left of central fixation). The square was associated with a left key-press response and the diamond was associated with a right key-press response for half of the participants (and vice versa for the other half of the participants).

A trial began with a centrally-located white fixation cross, presented on a black background until the participant had fixated within one degree of the centre of the screen for 200 ms (the fixation cross was presented for a minimum duration of 1000 ms). The stimulus display was presented for 2000 ms or until a key-press response was made to discriminate the target (whichever occurred earliest). The inter-stimulus interval was 1000 ms. See Figure 4.1C for an example of the trial sequence.

4.2.5 Data Preparation

Exclusion criteria. In addition to the general exclusion criteria outlined in Section 3.2.5, trials were also removed if the accurate or inaccurate first saccade latency was more than 3 standard deviations away from the participant's mean accurate or inaccurate first saccade latency, respectively. 7.55% of the trials were removed based on the exclusion criteria. The amplitude of the initial saccade was smaller than 1 degree in 3.65% of the trials; in these cases, the initial saccade was removed and replaced by the subsequent saccade.

For the manual responses, the percentage of target discrimination errors was calculated in each condition for every participant. Following this, each inaccurate manual response RT was paired with a corresponding accurate manual response RT (for each participant). These correct responses were removed from further analyses to eliminate the effect of fast guesses (Eriksen, 1988); 2.41% of the correct responses were excluded from the RT analysis on the above criteria.

Participant characteristics. The mean total scores and the internal consistency for each questionnaire measure are provided in Table 4.1. Three participants were regarded as outliers; there were two outliers on the pre-test state anxiety measure (pre STAI-S) and there was one age outlier. All of the significant effects reported in the results section were replicated when the analyses were repeated following the removal of these outliers. Therefore, these participants were retained in all of the analyses outlined below. Independent t-tests revealed that there were no significant differences between males and females in the scores on any of the questionnaires, $ts < 1.5$, *ns*. In the current sample, 17 participants (28%) scored equal to or more than 46 on the STAI-T, 4 participants (7%) scored equal to or more than 46 on the pre-test measure of the STAI-S, 2 participants (3%) scored equal to or more than 46 on the post-test measure of the STAI-S and 18 participants (30%) scored equal to or more than 31 on the SIAS.

The inter-correlations between the measures of individual differences and age are presented in Table 4.2. Note that Spearman's correlations were conducted with age, pre STAI-S, SIAS and ACS due to their skewed distribution; Pearson's correlations were conducted in all other cases because the scores on the remaining questionnaire measures were normally distributed. As expected, the anxiety measures were positively correlated with one another and negatively correlated with attentional control.

Table 4.1. *Descriptive statistics and internal consistency for the questionnaire measures and age.*

	M	*SD*	*Minimum (lower limit)*	*Maximum (upper limit)*	*Cronbach's α*
Trait Anxiety (STAI-T)	39.93	9.72	24 (20)	65 (80)	.92
State Anxiety (pre STAI-S)	32.73	8.08	20 (20)	61 (80)	.91
State Anxiety (post STAI-S)	31.47	6.78	20 (20)	50 (80)	.85
Social Interaction Anxiety (SIAS)	23.05	12.90	3 (0)	55 (76)	.95
Attentional Control (ACS)	51.37	7.90	38 (20)	72 (80)	.83
Age (in years)	18.52	1.94	16	27	*na*

Table 4.2. *Inter-correlations between self-reported anxiety and attentional control measures and age*

	1	2 [a]	3	4 [a]	5 [a]	6 [a]
1. Trait Anxiety (STAI-T)	-	.55***	.45***	.64***	-.37**	.01
2. State Anxiety (pre STAI-S) [a]		-	.72***	.35**	-.38**	-.05
3. State Anxiety (post STAI-S)			-	.27*	-.39**	.07
4. Social Interaction Anxiety (SIAS) [a]				-	-.23†	.04
5. Attentional Control (ACS) [a]					-	.00
6. Age (in years) [a]						-

[a] Spearman's r_s was calculated with these variables due to their skewed distribution (Pearson's *r* was calculated for all other variables).

*** $p < .001$, ** $p < .01$, * $p < .05$, $^{\dagger}p < .10$

4.2.6 Data Analysis

Separate analyses were conducted for the eye movement and RT data. The analysis considered whether anxiety was associated with an inability to regulate orienting responses using eye movement data. In addition, the analysis provided a comparison with previous studies considering the relationship between anxiety and interference from threatening distractors using RT data.

Multiple regression analyses were conducted to assess whether anxiety or attentional control predicted the percentage of directional errors executed to threatening distractors (i.e., attentional capture by threat) or the delay in first saccade latencies to the target in the presence of threatening distractors. Significant effects were followed up with post-hoc regression analyses to establish whether they were observed across distractor eccentricities. These post-hoc analyses provided a means of identifying the selective attentional mechanisms underlying an inability to regulate orienting responses in anxiety (i.e. delayed disengagement from central threat or impaired inhibition of threat at all distractor eccentricities). The forced entry method was used; the five predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety and attentional control) were entered into the regression model simultaneously. Finally, exploratory correlations were conducted between the dependent variables and the interaction term for state anxiety x trait anxiety (for the pre- and post-test measures of state anxiety separately), the interaction term for trait anxiety x attentional control and the separate attentional focusing and attentional shifting subscales of the ACS. These analyses were also repeated with the RT data.

The basic effects associated with the remote distractor paradigm were considered using repeated measures ANOVAs and paired-sample t-tests to establish whether the dependent variables were influenced by distractor presence (vs. absence), distractor eccentricity and distractor expression across participants.

4.3 Results

4.3.1 Directional Errors

This analysis focused on the percentage of directional errors in the presence of threatening and non-threatening distractors across participants and as a function of anxiety and attentional control. Directional errors could only occur in parafoveal and peripheral distractor trials because these were the only conditions in which a first saccade could be directed towards a distractor face. Therefore, the single target and central distractor trials were excluded from the following analysis.

Basic effects. The error rate (i.e. the percentage of directional errors) was negatively skewed across experimental conditions due to near ceiling performance in many participants and this could not be corrected by transforming the data. Therefore non-parametric tests were used. The Wilcoxon signed rank test revealed that the error rate was significantly higher in the peripheral distractor condition (*Mdn* = 4.79%) compared with the parafoveal distractor condition (*Mdn* = 2.19%), $z = 4.10$, $p < .001$, $r_w = 0.53$. A Friedman's ANOVA revealed that the error rate did not differ between expressions, $\chi^2(2) = 1.38$, *ns* (*Angry Mdn* = 3.18%; *Happy Mdn* = 3.71%; *Neutral Mdn* = 3.81%).

Anxiety. It was not appropriate to conduct multiple regressions on the directional error data because the assumptions of regression analyses were not met. Specifically, there was a violation of the assumption of normally distributed residuals. Therefore, Spearman's correlations were conducted to assess the relationship between the measures of individual differences and the directional error rates for parafoveal and peripheral distractors separately and for each expression separately. There were no significant correlations in any experimental condition or for any measure of individual differences, $|r_s| < .25$, $ps > .05$. This suggests that neither anxiety nor attentional control were associated with attentional capture by threatening or non-threatening distractors. Spearman's correlations between the interaction terms (trait anxiety x pre state anxiety, trait anxiety x post state anxiety and trait anxiety x attentional control) and the directional errors for each expression were non-significant, $ps > .10$, *ns*. Spearman's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the dependent variables were also non significant for each expression, $ps > .10$, *ns*.

4.3.2 Latency of Accurate First Saccades to the Target

This analysis focused on the time taken to initiate an accurate saccade to the target in the presence and absence of threatening and non-threatening distractors across participants and as a function of anxiety and attentional control.

Single target trials. It was important to verify that performance was consistent in the single target trials across each of the experimental blocks; the experiment was blocked by distractor expression and this raised the possibility that the effect of a particular type of distractor could carryover from the distractor trials to the single target trials within an experimental block. A one-way (single target condition: angry block, happy block, neutral block) repeated measures ANOVA on the latency of the first saccade to the target revealed that the first saccade latencies did not significantly differ ($F < 1.1$, *ns*) between the single target trials in the angry ($M = 209.91$, $SD = 39.19$), happy ($M = 203.95$, $SD = 36.10$) and neutral ($M = 208.33$, $SD = 46.24$) blocks.

Remote Distractor Effect (RDE). The statistical significance of the RDE was assessed across participants by conducting paired samples t-tests. For each distractor expression and each distractor eccentricity, the latency of the accurate first saccades in the distractor trials was compared with the single target trials embedded within the same block. First saccade latencies were significantly shorter in the single target trials compared with all of the distractor conditions (all $ts > 5$, all $ps < .001$, all $ds > 0.33$). The presence of a distractor delayed the first saccade to the target, irrespective of the expression or the eccentricity of the distractor, indicating a reliable RDE. The presence of this RDE highlights the validity of this modified version of the remote distractor paradigm. Figure 4.2 shows the magnitude of the RDE for each distractor expression at every distractor eccentricity.

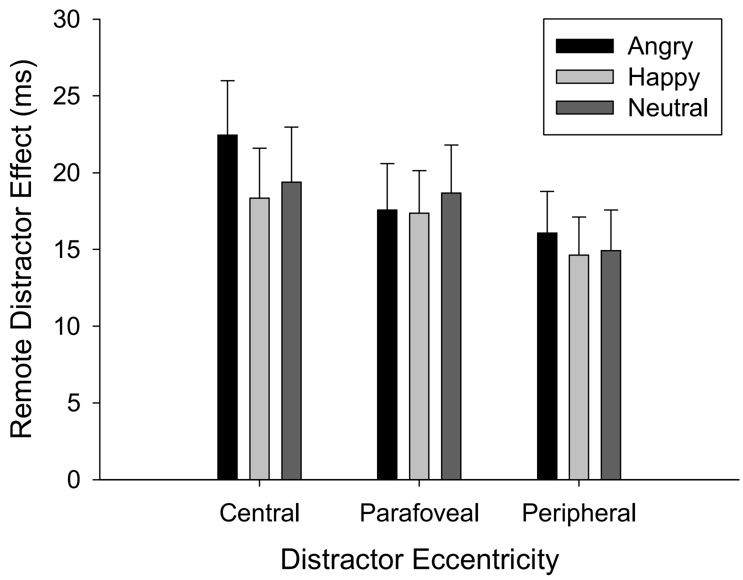

Figure 4.2. Mean (+*SE*) for the remote distractor effect (RDE) as a function of distractor eccentricity and distractor expression.

Distractor trials. A 3 (distractor eccentricity) x 3 (distractor expression) repeated measures ANOVA on the latency of the accurate first saccades to the target revealed a main effect of eccentricity that approached significance, $F(1.70, 100.01) = 3.14$, $p = .056$. Pairwise comparisons showed that first saccade latencies were longer in the presence of central distractors ($M = 227.46$, $SD = 30.60$) compared with peripheral distractors ($M = 222.59$, $SD = 31.68$, $p < .05$, $d = 0.16$). First saccade latencies to the target in the presence of parafoveal distractors ($M = 225.26$, $SD = 33.23$) did not differ significantly from central or peripheral distractors. Thus, first saccade latencies increased as distractor eccentricity decreased.

There was a trend towards a main effect of expression, $F(2, 118) = 2.39$, $p = .096$, where first saccade latencies were longer for angry distractors ($M = 228.61$, $SD = 31.45$) compared with happy distractors ($M = 220.72$, $SD = 34.24$, $p = .061$, $d = 0.24$). First saccade latencies to the target in the presence of neutral distractors ($M = 225.98$, $SD = 38.27$) did not significantly differ from angry or happy distractors and, therefore, it remains unclear whether the effect of expression was driven by greater distractor interference from angry faces or reduced distractor interference from happy faces. The interaction between expression and eccentricity was not significant, $F < 1.5$, *ns*. See Figure 4.3 for the latency of the first saccade to the target as a function of distractor eccentricity and distractor expression.

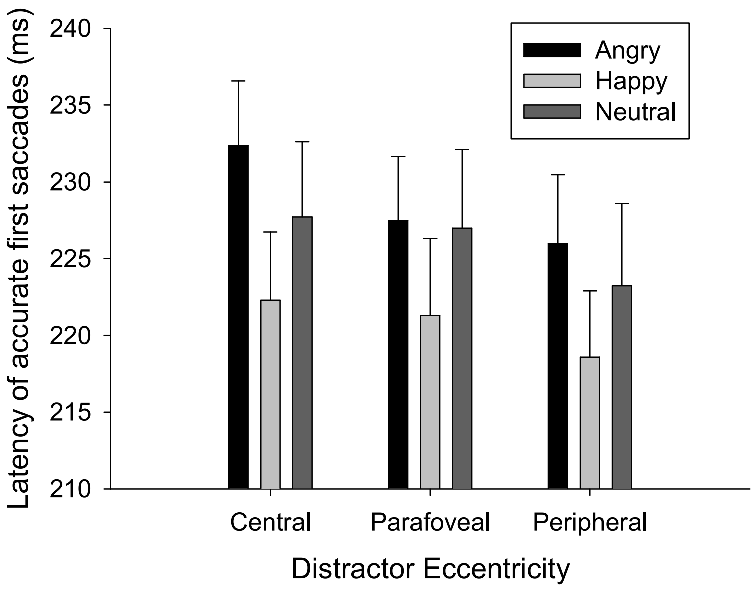

Figure 4.3. Mean (+*SE*) for the latency of accurate first saccades as a function of distractor eccentricity and distractor expression.

Anxiety. In order to assess whether anxiety or attentional control affected baseline eye movement performance, the latency of the first saccades to the target in the baseline single target trials was regressed against the five predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety and attentional control). The regression model was not significant $R^2 = .10$, $F = 1.16$, *ns* and there were no significant predictors within the model $|\beta s| < .27$, *p*s > .05. However, there was a trend towards higher levels of attentional control predicting a decrease in first saccade latencies; that is, an increased ability to focus and shift attention was associated with faster initiation of an eye movement to the target (see Table 4.3).

In order to consider the relationship between the measures of individual differences and distractor interference from threatening and non-threatening faces, the five predictors were regressed against the latency of the accurate first saccades to the target in the distractor trials for each expression separately (see Table 4.3). Table 4.3 shows that the regression models were non-significant for happy distractor trials and neutral distractor trials, R^2s < .12, *F*s < 1.3, *ns* and, furthermore, there were no significant predictors within these models, $|\beta s| < .30$, *p*s > .05. However, in line with the baseline single target trials, there was a trend towards higher levels of attentional control predicting a decrease in first saccade latencies to the target.

Importantly, the regression model was significant for angry distractor trials, $R^2 = .21$, $F(5, 54) = 2.80$, $p < .05$, and trait anxiety was a significant predictor within this model, $\beta = .42$, $p < .05$ (see Table 4.3). In addition, there was a further trend towards higher levels of attentional control predicting a decrease in first saccade latencies to the target. The regression analysis on the angry distractor trials was repeated after excluding the statistically redundant variables (Field, 2005) such that trait anxiety was entered as the only predictor and the latency of the accurate first saccades was entered as the dependent variable. Trait anxiety was still a statistically significant predictor of the latency of the accurate first saccades in the angry distractor trials, $R^2 = .08$, $F(1, 58) = 4.77$, $\beta = .28$, $p < .05$, indicating that the latency of accurate first saccades increased as trait anxiety increased, but only in the presence of an angry distractor. That is, increasing anxiety was associated with greater interference from threatening distractors.

Further analyses considered whether the relationship between trait anxiety and distractor interference from threat occurred at all distractor eccentricities. The latency of the accurate first saccades in the presence of angry distractors was regressed against trait anxiety for each of the three distractor eccentricities separately (see Figure 4.4). Trait anxiety was a significant predictor of the latency of the accurate first saccades in the presence of central angry distractors, $R^2 = .10$, $F(1, 58) = 6.33$, $\beta = .31$, $p <.05$. There was also a trend towards trait anxiety predicting the latency of the accurate first saccades in the presence of parafoveal angry distractors, $R^2= .05$, $F(1, 58) = 3.22$, $\beta = .23$, $p = .078$ and peripheral angry distractors, $R^2 = .06$, $F(1, 58) = 3.57$, $\beta = .24$, $p = .064$. A follow-up regression analysis was conducted in which the latency of the accurate first saccades from the single target trials in the angry block was regressed against trait anxiety. Trait anxiety did not reach criterion for statistical significance, $R^2 = .02$, $F < 1.5$, $\beta = .16$, *ns*, highlighting that the relationship between anxiety and eye movements to the target did not occur in the single target trials embedded in the angry block.

Spearman's correlations between the interaction terms (trait anxiety x pre state anxiety, trait anxiety x post state anxiety and trait anxiety x attentional control) and the dependent variables for the distractor trials for each expression were non-significant, *ps* > .10, *ns*, indicating that enhanced distractor interference from threat was not specific to high trait anxious individuals who were high in state anxiety or low in attentional control.

The regression analyses revealed a trend towards high levels of attentional control predicting a decrease in first saccade latencies to the target; therefore, it was of particular interest to conduct exploratory correlations between the two separate subscales from the ACS (attentional shifting and attentional focusing) and the latency of accurate first saccades for the baseline single target trials and the distractor trials for each expression separately. There were no significant correlations between attentional focusing scores and the latency of accurate first saccades for any condition, *rs* > -.23, *ps* > .05, *ns*. In contrast, there were significant correlations between attentional shifting scores and the latency of accurate first saccades to the target in the baseline single target trials ($r = -.30$, $p < .05$), angry distractor trials ($r = -.31$, $p < .05$), happy distractor trials ($r = -.33$, $p < .05$) and neutral distractor trials ($r = -.29$, $p < .05$). Therefore, the relationship between attentional control and the latency of the first saccade to the target was specific to attentional shifting; that is, high levels of self-reported attentional shifting abilities were associated with rapid shifts in overt attention (i.e. faster first saccade latencies) towards the target, irrespective of the presence or absence of a distractor.

4.3.3 Target Discrimination Reaction Times

This analysis focused on the time taken to make a target discrimination response in the presence and absence of threatening and non-threatening distractors across participants and as a function of anxiety and attentional control (for correct responses only; note that the error rates were less than 4% in all conditions).

Single target trials. In order to confirm that single target performance was consistent across the experimental blocks, a one-way (single target condition; angry block, happy block, neutral block) repeated measures ANOVA was conducted on the reciprocal of the RT to discriminate the target and revealed that RTs did not significantly differ, $F < 1$, *ns*, between single target trials in the angry ($M = 0.00151$, $SD = 0.00027$), happy ($M = 0.00152$, $SD = 0.00025$) and neutral ($M = 0.00149$, $SD = 0.00023$) blocks. See Table 4.4 for descriptive statistics on the RTs in the single target conditions.

Distractor interference. Paired samples t-tests were conducted to assess whether the presence of a distractor delayed RTs to discriminate the target in comparison with the single target trials. For each distractor expression and each distractor eccentricity, the reciprocal of the RTs in the distractor trials was compared with the single target trials embedded within the same block. RTs were significantly longer in trials containing central and peripheral distractors compared with single target trials, irrespective of distractor expression (all $ts > 3$, all $ps < .01$, all $ds > 0.11$). However, RTs did not significantly differ between parafoveal distractor trials and single target trials for any expression, $ts < 2.5$, *ns*. The presence of a distractor delayed RTs to discriminate the target but only for distractors presented at central or peripheral regions of the visual field.

Distractor trials. A 3 (distractor eccentricity) x 3 (distractor expression) repeated measures ANOVA on the reciprocal of the RT to discriminate the target revealed a main effect of eccentricity, $F(2, 118) = 16.98$, $p < .001$. Pairwise comparisons showed that RTs were shorter in the presence of parafoveal distractors ($M = 0.00150$, $SD = 0.00024$) compared with central distractors ($M = 0.00147$, $SD = 0.00022$, $p < .001$, $d = 0.13$) and peripheral distractors ($M = 0.00147$, $SD = 0.00023$, $p < .001$, $d = 0.13$). The effect of expression and the interaction between expression and eccentricity were non-significant, $Fs < 1.5$, *ns*. See Table 4.4 for descriptive statistics on the RTs in the distractor conditions.

Anxiety. Finally, the reciprocal of the RTs was regressed against the five anxiety and attentional control predictors for the baseline block of single target trials and the distractor trials for each expression separately. There were no significant regression models, $R^2 < .13$, *Fs* < 2, *ns*, and no significant predictors within the models, $|\beta s| < .30$, *ps* > .05. Spearman's correlations between the interaction terms (trait anxiety x pre state anxiety, trait anxiety x post state anxiety and trait anxiety x attentional control) and the dependent variables were non-significant for each expression, *ps* > .10, *ns*.

Pearson's correlations were also conducted between the two separate subscales of the ACS (attentional shifting and attentional focusing) and the reciprocal of the RTs for the baseline block of single target trials and the distractor trials for each expression separately. There were no significant correlations between scores on the attentional shifting subscale and the reciprocal of the RTs for any condition, *ps* > .10, *ns*. Scores on the attentional focusing subscale did not correlate significantly with the reciprocal of the RTs in the baseline single target trials ($r = .21$, $p > .10$); however attentional focusing was correlated with the reciprocal of the RTs in the angry distractor trials ($r = .32$, $p < .05$), happy distractor trials ($r = .28$, $p < .05$) and, albeit non-significantly, the neutral distractor trials ($r = .25$, $p = .051$). Thus, the time taken to discriminate the target with a manual response decreased with increasing levels of self-reported attentional focusing abilities, but only in the presence of a distractor. That is, distractor interference was greater for individuals reporting low levels of attentional focusing abilities.

4.3.4 Item Analysis

All of the above ANOVAs/ non parametric tests were repeated on the model means rather than the participant means. All of the significant effects involving eccentricity and expression reported in the preceding analyses were replicated in the item analysis. Therefore, the significant effects reported here cannot be attributed to individual models.

Table 4.3. *Regression analyses on the latency of the accurate first saccades to the target.*

	Angry Distractors [a]			Happy Distractors[b]			Neutral Distractors[c]			Baseline Single Target[d]		
	B	*SE*	*β*	*b*	*SE*	*B*	*b*	*SE*	*β*	*b*	*SE*	*B*
Trait Anxiety (STAI-T)	1.37	0.58	.42*	0.48	0.68	.14	1.13	0.75	.29	0.39	0.97	.08
State Anxiety (pre STAI-S)	-1.25	0.67	-.32†	-0.16	0.78	-.04	-0.54	0.87	-.11	-1.51	1.12	-.25
State Anxiety (post STAI-S)	0.91	0.78	.20	0.77	0.91	.15	-0.35	1.01	-.06	0.80	1.31	.11
Social Anxiety (SIAS)	-0.52	0.39	-.21	-0.38	0.46	-.14	-0.53	0.51	-.18	-0.46	0.66	-.12
Attentional Control (ACS)	-0.95	0.53	-.24†	-0.78	0.62	-.18	-1.19	0.69	-.25†	-1.64	0.89	-.26†

[a]$R^2 = .21$, $F(5, 54) = 2.80$, $p < .05$; [b,c,d]$R^2 < .12$, $F < 1.3$, *ns*; *$p < .05$; †$p < .10$

Table 4.4. *Mean (+SD) for the reaction times (ms) to discriminate the target as a function of experimental block and distractor condition.*

	Baseline Block		Angry Block		Happy Block		Neutral Block	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Single target	781.89	146.82	710.13	130.54	705.11	127.94	716.82	129.72
Central distractor	-	-	723.63	125.84	723.71	135.02	729.17	127.25
Parafoveal distractor	-	-	710.27	140.74	718.39	144.92	709.46	135.34
Peripheral distractor	-	-	724.21	136.35	717.77	136.04	734.56	132.70

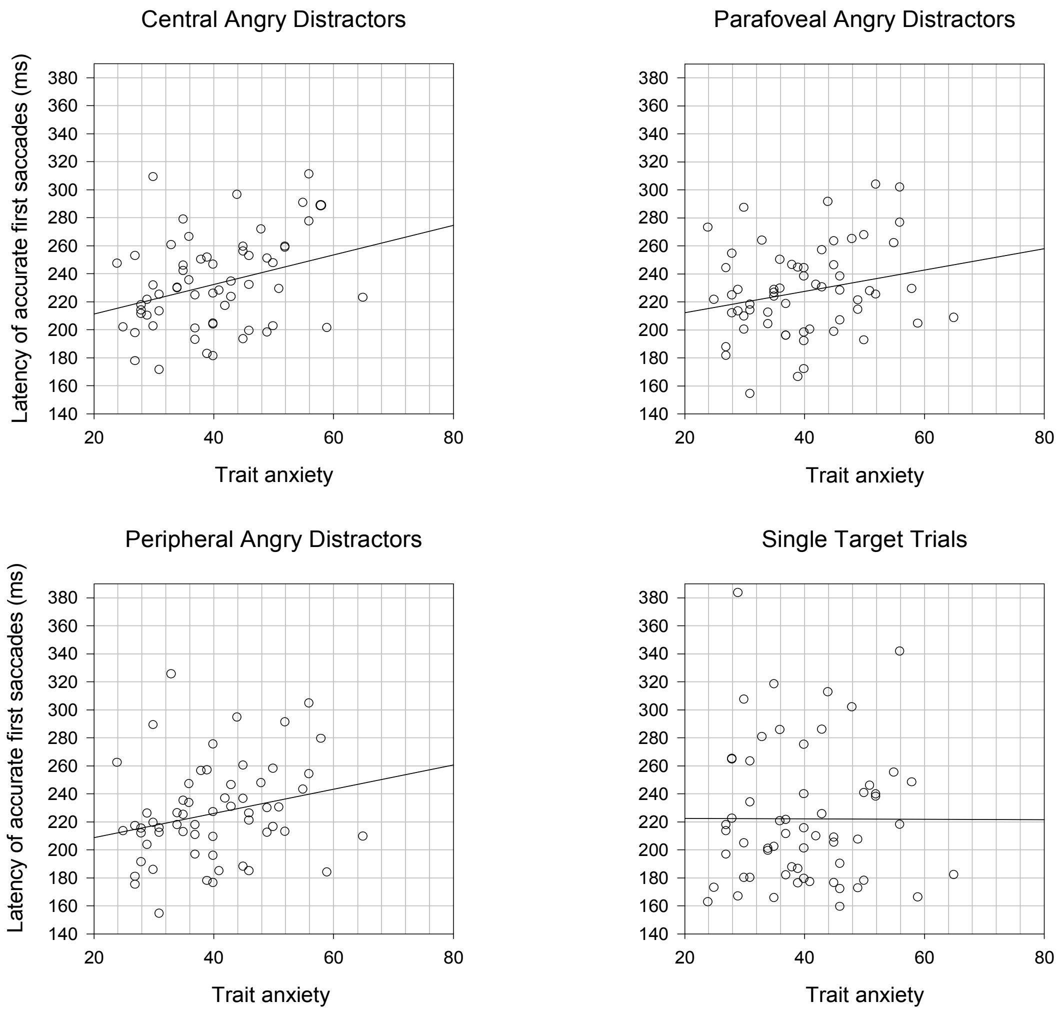

Figure 4.4. Mean latency of accurate first saccades to the target as a function of trait anxiety and the eccentricity of the angry distractor (vs. single target trials).

4.4 Discussion

The current study explored the possibility that anxiety is associated with greater interference from threatening (but not non-threatening) distractors. The eccentricity of the threatening distractor was manipulated to distinguish between two propositions: firstly, that anxious individuals selectively focus attention on threat when it is task-irrelevant and where it competes for attentional resources with task-relevant neutral stimuli and; secondly, that anxiety is associated with a broad focus of attention and an inability to focus attention on an ongoing task when threats are present in the environment. Finally, the current study aimed to provide a comparison with previous literature on anxiety and the ability to inhibit threat processing by considering the effect of threatening and non-threatening distractors on manual RTs to discriminate the target.

In line with previous eye movement research using the remote distractor paradigm (Benson, 2008b; Walker et al., 1997), there was a reliable RDE in the current study; the latency of the first saccade to the target was shorter in the single target trials compared with the distractor trials, irrespective of the eccentricity or the expression of the distractor face. Furthermore, the latency of the first saccade to the target and the magnitude of the RDE increased as the eccentricity of the distractor decreased (Walker et al., 1997). The percentage of directional errors was greater for peripheral distractors compared with parafoveal distractors (see also Benson, 2008b).

The primary aim of the current study was to assess whether anxiety was associated with an inability to regulate orienting responses in the presence of threatening distractors and to identify the attentional processes that are impaired as a consequence of a failure to inhibit threat processing. There was evidence to suggest that trait anxiety was linked to greater interference from threatening distractors. However, the percentage of directional errors to threatening faces was not influenced by anxiety, suggesting that anxious individuals were able to suppress exogenous saccades towards threatening distractors in parafoveal and peripheral regions of the visual field.

Trait anxiety was associated with longer latencies to initiate a saccade to the target, but only in the presence of threatening distractors. This finding suggests that individuals with high levels of anxiety found it difficult to inhibit threat processing and, consequently, were slow to voluntarily execute an endogenous saccade to the target in the presence of threat. Although the relationship between anxiety and interference from threat was particularly evident when the angry distractor was presented in central locations, there was also a tendency for the relationship to occur when the angry distractor was presented in parafoveal and peripheral regions. It is possible that the relationship between anxiety and interference from threat was at its greatest magnitude for central distractors because it is more difficult to ignore stimuli that fall within foveal vision. Alternatively, given that visual acuity is enhanced in the fovea (Findlay & Gilchrist, 2003; Liversedge & Findlay, 2000), it is possible that threatening information of a higher quantity and quality was extracted from central regions of the visual field. However, the results are important in suggesting that interference from threat occurred across the visual field and was not dependent on foveal processing.

Taken together, the current findings are highly consistent with those reported by Derakshan et al., (2009), who found that angry face cues delayed the latency of antisaccades, but did not affect the proportion of incorrect prosaccades, in high trait anxious individuals. They concluded that there was a difficulty in inhibiting threat processing in high trait anxious individuals. The current study extended this work by considering interference from threat in a task where threatening stimuli were task-irrelevant and competed for attention with a task-relevant neutral stimulus. By adopting this approach, the current study replicated the finding that anxiety is associated with a delay in inhibiting threat processing and that it is not associated with involuntary eye movements towards threat.

The approach used in the current work also extended the existing empirical literature by providing an account of the attentional processes that underlie the inability to regulate orienting responses in the presence of task-irrelevant threat. In line with the previous experiment, the current results were inconsistent with the notion that anxious individuals selectively attend to threat with a narrow focus of attention (e.g., Williams et al., 1997). Anxiety was not characterised by an inability to prevent the spotlight of attention moving towards threatening distractors (i.e. attentional capture). Although there was evidence to support the proposition that individuals with high levels of anxiety find it particularly difficult to disengage attention from threat presented in central regions of the visual field (Fox, 1996; Fox et al., 2001, 2002; Georgiou et al., 2005), this distractor interference from threat also extended to peripheral regions of the visual field. Therefore, the findings suggest links between anxiety and an ability to extract threatening information from a broad attentional beam. The zoom lens metaphor of attention suggests that a broad distribution of attention enhances processing of a target stimulus (Cave & Bichot, 1999; Eriksen & St James, 1986) and facilitates threat detection in anxious individuals (Eysenck et al., 2007) when the location of the target/threat stimulus is not known in advance. The presence/absence and location of the threatening distractor varied from trial-to-trial in the current study and, therefore, maintaining a broad distribution of attention would facilitate threat processing in this context.

The current study considered the effect of attentional control. Consistent with predictions, attentional control was inversely related to anxiety. It has been proposed that attentional control is related to the ability to regulate orienting responses (Derryberry & Reed, 2002) and that it is involved in functions such as inhibition (i.e. inhibiting distractor interference; Eysenck et al., 2007). Therefore, it was expected that low levels of attentional control would lead to greater distractor interference. Interestingly, the results showed a dissociation between eye movement and RT measures and, furthermore, a dissociation between the attentional focusing and attentional shifting subscales of the ACS. The results indicated that low levels of attentional shifting abilities were related to slower orienting to the target, irrespective of the presence or absence of a distractor. In contrast, low levels of attentional focusing abilities were associated with greater distractor interference such that RTs to respond to the target were slowed, but only in the presence of a distractor. The results are important in suggesting that low levels of attentional control have a negative effect on task performance. Therefore, the current study highlights the validity of the separate subscales of the ACS as measures of attentional shifting and attentional focusing abilities.

The results also showed that RTs were generally delayed by the presence of a distractor. There was no evidence to suggest that anxiety was associated with greater interference from threatening (or non-threatening) distractors on the manual response task. In contrast, a small number of RT studies have provided some evidence to suggest that threatening distractors delay RTs to respond to a target, but only if they are presented within focal vision (Fox, 1993, 1994, 1996; Georgiou et al., 2005). One explanation for the difference between these studies is that in the current experiment, the primary task in each trial was to direct the eyes to a particular object and the subsequent task was to discriminate the target once the eyes landed on this object. In this study the manual response can be regarded as a secondary component of the task. In contrast, the manual response was the only task requirement in the studies by Fox et al. (Fox, 1993, 1994, 1996; Georgiou et al., 2005). However, the interpretation of these previous RT studies is complicated by the fact that the participants were required to maintain central fixation, thereby enhancing processing of the stimuli presented within foveal vision and reducing processing of the stimuli presented outside foveal vision.

One potential limitation in the current experiment was that although the basic eye movement effects associated with the paradigm were significant and in the anticipated direction, the magnitude of these effects was smaller than has previously been reported (Walker et al., 1997). Firstly, the effect of eccentricity was small (approximately a 5 ms difference between central and peripheral distractors). The RDE for distractors at all eccentricities was between 10 ms and 30 ms. While this is a typical RDE for parafoveal and peripheral distractors, central distractors typically delay eye movements to the target by 30-40 ms (Walker et al., 1997). Secondly, there were a low percentage of directional errors in the present data (2% for parafoveal distractors and 5% for peripheral distractors). Benson (2008b; Experiment 3) reported directional error rates of 20% for parafoveal distractors and 28% for peripheral distractors. One possible explanation for the small effects in the current study is that the target and distractors were easily identifiable and highly dissimilar in terms of size, shape and colour. Therefore, it was easy to identify and discriminate between the target and distractors quickly and without moving the eyes to the distractor.

In summary, the findings from the current study concur with the notion that anxiety is associated with greater distractibility from threatening stimuli. The results were consistent with the proposition that there is hypervigilance for threat and a broad focus of attention in anxiety (Eysenck, 1992). The current study highlighted that, for anxious individuals, the cost of a broad focus of attention is greater distractibility in the presence of task-irrelevant threat. However, from an empirical perspective, it remains unclear whether there is a benefit in maintaining a broad focus of attention in anxiety. Theoretical models of anxiety, for example, would suggest that a broad distribution of attention facilitates threat detection (Eysenck, 1992; Eysenck et al., 2007). These issues are considered in the following experiment.

Chapter 5 : Anxiety and Processing Capacity for Threat Detection

5.1 Introduction

Hypervigilance theory (Eysenck, 1991) and ACT (Eysenck et al., 2007) propose that individuals with high levels of anxiety adopt a hypervigilant attentional style, which reduces attentional focus on the ongoing task in order to facilitate threat detection. Specifically, Eysenck et al., (1992, 2007) raised the possibility that, prior to threat detection, anxious individuals are hypervigilant for threat across the visual field, where this is accomplished by adopting a broad focus of attention with few eye movements or alternatively by scanning the environment with a narrow focus of attention.

Visual search studies measuring RTs provide evidence of enhanced detection of singleton threat in anxious individuals (Byrne & Eysenck, 1995; Matsumoto, 2010). In these studies, it is unclear whether this improved performance occurs in the context of a broad focus of attention. It is possible that the benefits of a broad focus of attention would be particularly apparent when there is a possibility that multiple threats could occur simultaneously in different locations. In this scenario, a broadly tuned attentional system should allow monitoring for threat across the visual field and the integration of threatening stimuli from multiple locations. The current study used an RT redundant signals paradigm and concurrent eye movement measures to consider the relationship between threat detection and the breadth of attention in anxiety in the context of single and multiple threats. Importantly, this study aimed to understand the cognitive mechanisms that allow anxious individuals to detect threat with greater efficiency.

5.1.1 The Redundant Signals Paradigm

The redundant signals paradigm has been used to consider target detection in the presence of single and multiple targets. In this paradigm, displays are presented in which there are no targets present (target absent condition), one target present (single target condition) or two targets present (redundant target condition). Participants are asked to make a target present response if they see at least one target and to make a target absent response if there are no targets in the display. In other words, one target is adequate for a target present response. A typical finding is that there is a redundancy gain (or redundant signals effect), which is an improvement in accuracy or RTs with the addition of a redundant target (Grice & Canham, 1990; Zehetleitner, Müller, & Krummenacher, 2008). The RT redundancy gain can occur as a result of statistical facilitation (e.g. race models (Raab, 1962)) or co-activation of target signals (Miller, 1982). In distinguishing between these accounts, it is necessary to analyse the RT distribution (Miller, 1982) and, specifically, to consider whether the fastest RTs in the redundant target condition can be predicted from the fastest RTs in the faster of the single target conditions.

Race models (Raab, 1962) assume that a redundant target trial is comprised of a parallel race between two independent signals. These models propose that the RT distribution associated with each independent signal in the redundant target condition is equivalent to the RT distributions for the corresponding signals in the two separate single target conditions (Zehetleitner et al., 2008). In the redundant target trial, the detection response is triggered when the quicker of the two independent signals exceeds a threshold level of activation. Therefore, the response on any one redundant target trial is never faster than the minimum time taken to respond to either of the single targets separately. However, on average, RTs will be faster in the redundant target condition because this average is based on the quickest responses from the two single target conditions. Thus, the redundancy gain at the level of the mean RT occurs as a result of statistical facilitation (Raab, 1962).

Co-activation models suggest that information from the two target signals is combined prior to the response and, therefore, activation accumulates and exceeds the threshold required for response initiation at a greater rate in redundant target trials (Miller, 1982; Townsend & Nozawa, 1995). The integration of activation from two signals produces responses that are faster than the minimum time taken to respond to either of the single targets separately. Thus, co-activation models predict that the redundancy gain will be greater than that expected by statistical facilitation. Miller (1982) developed the race model inequality to distinguish between co-activation and race model accounts of the redundancy gain. This inequality is based on the cumulative distribution function (CDF) of RTs and provides the upper bound of the redundancy gain that can occur due to statistical facilitation. Specifically, the race model inequality states that the CDF of the RTs in the redundant target condition should not exceed the sum of the CDFs for the single target conditions at any point in time. In other words, the probability of responding at or before time T should not be greater in the redundant target condition compared with the sum of the single target conditions for all values of T. A violation of the inequality indicates that the fastest responses in the redundant target condition were faster than the fastest responses in the single target conditions; this finding is consistent with co-activation models.

The lower bound of the race models is provided by the Grice inequality (Grice, Canham, & Gwynne, 1984). Race models predict that the processing time in the redundant target condition should be at least as fast as the processing time in the fastest of the single target conditions. The Grice inequality states that the CDF for the redundant target condition should be greater than or equal to the CDF from the faster of the single target conditions. In other words, the probability of responding at or before time T in the redundant target condition should be greater than or equal to the fastest single target condition for all values of T. A violation of the Grice inequality indicates that RTs are slower in the redundant target condition compared with at least one of the single target conditions and, therefore, performance in the redundant target condition is worse than that predicted by race models.

Recently, the mathematical inequalities developed by Miller and Grice have been extended to consider processing capacity (Townsend & Nozawa, 1995). It has been argued that mean RTs only provide coarse information about the capacity of a system to complete a task and the average time taken to respond (Wenger & Gibson, 2004). They suggested that a more appropriate measure of processing capacity is to consider the work required to complete a task at each point in time across the RT distribution. Processing capacity refers to the amount of work that a system can perform at each point in time and, furthermore, the efficiency and speed with which the system can carry out a task with changes in workload (Townsend & Ashby, 1978; Townsend & Nozawa, 1995; Townsend & Wenger, 2004a; Townsend & Wenger, 2004b; Wenger & Gibson, 2004). In this case, the addition of a redundant target represents an increase in the amount of relevant information that needs to be processed (i.e., an increase in workload). Capacity is assessed by considering the change in processing efficiency associated with an increase in workload. Super-capacity processing occurs when processing efficiency improves with an increase in workload (e.g., speed of processing increases with the addition of a redundant target); limited capacity processing occurs when processing efficiency decreases with an increase in workload (e.g. speed of processing decreases with the addition of a redundant target) and; unlimited capacity processing occurs when processing efficiency neither improves nor deteriorates with an increase in workload. It has been argued that super-capacity processing should be associated with violations of the Miller inequality and very limited capacity processing should be associated with violations of the Grice inequality (Townsend & Nozawa, 1995).

The redundant signals paradigm has been used across a wide spectrum of research such as letter search (Miller, 1982; Müller, Humphreys, & Donnelly, 1994), face processing (Ingvalson & Wenger, 2005) and semantic word processing (Eidels, Townsend, & Algom, 2010). Miller (1982), for example, instructed participants to detect the presence of the target letter A in displays containing two distractors, a single target with a distractor, or two targets. There was a redundancy gain at the level of the mean RT and, furthermore, there were violations of the race model inequality at early time points in the RT distribution; providing evidence of co-activation of targets in letter search.

Similarly, Eidels et al., (2010) used the Miller inequality, Grice inequality and measures of processing capacity to consider whether Stroop interference occurred as a result of an interaction (i.e., co-activation) between the semantic content of a word and the colour it was printed in. Participants completed a redundant signals variant of the Stroop task in which the participant had to divide their attention between the colour and semantic content of the word. Participants were presented with a single word (RED or GREEN) which was either printed in the colour red or green. The participant had to detect the presence of red; target present trials could contain a single target (RED printed in green or GREEN printed in red) or two targets (RED printed in red). Target absent trials contained the word GREEN printed in green. Although there was evidence of a redundancy gain at the level of the mean RT, Eidels et al., (2010) found no violations of the Miller or Grice inequalities and measures of processing capacity were consistent with unlimited capacity processing. They concluded that, in the divided attention variant of the Stroop paradigm, the meaning of the word and print colour did not interact to co-activate a response despite their strong semantic connection.

The redundant signals methodology has also recently been used with facial expressions of emotion to address the possibility that the cerebral hemispheres interact in the perception of emotions (Tamietto, Adenzato, Geminiani, & de Gelder, 2007; Tamietto, Latini Corazzini, de Gelder, & Geminiani, 2006; Schweinberger, Baird, Blumler, Kaufmann, & Mohr, 2003). Tamietto et al. (2006, 2007), for example, presented an emotional expression in the right visual field only (RVF), the left visual field only (LVF), or the same emotional expression to both visual fields simultaneously (BVF) and instructed participants to press a button when a face expressed the target emotion and to withhold a response when it expressed a non-target emotion (i.e., a go/no-go paradigm). They argued that if the two hemispheres operate independently in the perception of emotional expressions, then a race will occur in which each hemisphere processes a face separately and the task will be completed when the faster hemisphere finishes processing. If the two hemispheres interact, then performance should be enhanced in the bilateral condition compared with the unilateral conditions. They found a bilateral advantage (i.e. redundancy gain) such that RTs to detect happy, fearful, flirtatious and arrogant facial expressions were faster in the BVF condition compared with the RVF and LVF conditions. Furthermore, this bilateral advantage violated the race model inequality and, therefore, was consistent with co-activation models, suggesting that the two hemispheres interact in the perception of emotions rather than processing the faces independently. (But see Schweinberger et al., 2003, who found no evidence of a bilateral gain in the recognition of happy and neutral faces).

5.1.2 The Current Study

The redundant signals paradigm was used in the current work to consider the relationship between the breadth of attention and threat detection in the presence of multiple (vs. single) threats in anxious and non-anxious individuals. Participants were asked to indicate whether an emotional face (threatening or non-threatening) was present or absent in displays containing no targets, one target or two targets. The primary aim of the study was to consider the cognitive mechanisms underlying enhanced threat detection in individuals with high levels of anxiety. Of particular interest was whether anxious individuals were able to pool evidence about the presence of threat from across the visual field by co-activation of target signals. A further important aim was to assess whether enhanced threat detection in anxiety occurred within a broad focus of attention (as indexed by eye movements).

It was predicted that there would be a redundancy gain for threatening targets in individuals with high levels of anxiety; that is, RTs to detect a target would be faster when multiple (vs. single) threats were present because anxious individuals would be hypervigilant for threat in multiple locations across the visual field. This redundancy gain could occur within a broad attentional beam or as a result of excessively scanning the visual field with numerous eye movements. A broad focus of attention would allow a co-active processing system to integrate information from multiple locations prior to threat detection and, therefore, the threshold for threat detection would be exceeded more rapidly if evidence of threat could be accumulated from multiple (vs. single) threat stimuli across the visual field. However, target redundancy would also lead to faster threat detection responses in a system that operates by scanning the environment with rapid eye movements because, on average, less scanning would be required before the eyes land on a threat when there are multiple (vs. single) threats in the visual field. Therefore, the redundancy gain cannot be used in isolation to distinguish between the possible attentional processes and cognitive mechanisms underlying threat detection in anxiety.

In the current study, processing capacity was measured across the RT distribution in order to further consider the possibility of a co-active processing architecture for threat detection in anxiety. By considering the RT distribution, processing capacity measures move beyond measures of average speed to provide information about the work required to detect a target at each point in time (Wenger & Gibson, 2004). If threatening information can be integrated from across the visual field, then less work should be required to detect threat at each point in time when there are multiple targets compared with single targets because evidence for the presence of threat will accumulate more rapidly in the former condition. This is consistent with super-capacity processing, where an increase in workload (i.e. an increase in the number of threats to be processed) is associated with greater processing efficiency.

Processing capacity was assessed at the level of the hazard function of the RT distribution. This approach is an extension of survival analysis. The hazard function of the RT distribution gives the probability that a task will be completed in the next instant of time, given that it has not already been completed. The hazard function provides a measure of instantaneous capacity to complete a task at each point in time across the RT distribution and, as such, provides greater detail than the average time taken to complete a task (i.e. mean RT; see Townsend & Ashby, 1978; Wenger & Gibson, 2004). Given a sufficiently large number of observations per participant and per experimental condition, the hazard function can be used to make qualitative distinctions between limited, unlimited and super-capacity processing. If there are fewer observations, as is the case in the current study, then a different approach is required. Specifically, semi-parametric regression models (e.g., the Cox Proportional Hazards Model) are used to assess the effect of independent variables on the orderings of the hazard functions (Wenger & Gibson, 2004; Wenger, Negash, Petersen, & Petersen, 2010). See further details in Section 5.2.6.

Predictions concerning the relationship between anxiety and processing capacity for threat detection depend on whether individuals with high levels of anxiety adopt a broad focus of attention or excessively scan the environment with a narrow focus of attention (i.e. using rapid eye movements). Based on the evidence from the previous experiment, it was predicted that the optimal strategy for threat detection would be to maintain a broad focus of attention rather than to narrow attention onto individual targets. Evidence for this broadening can be highlighted from eye movement measures; if anxious individuals maintain a broad focus of attention in order to facilitate threat detection and processing from all possible locations, then they should be more inclined to keep their eyes still in order to allocate attentional resources widely. Therefore, anxiety would be associated with a decrease in the frequency of eye movements and increased processing capacity to detect multiple (vs. single) threats due to co-activation of target signals across the visual field. A contradictory prediction was that anxious individuals would excessively scan the environment with a narrow focus of attention and that this would lead to an increase in the frequency of eye movements and no evidence of increased processing capacity to detect multiple (vs. single) threats because it would not be possible to co-activate target signals falling outside the focus of attention.

5.2 Method

5.2.1 Participants

Forty healthy adults participated in the experiment (*mean age* = 22.00 years, *SD* = 3.34, *range* = 18-29 years; 11 males).

5.2.2 Stimuli

The faces used in this experiment were a subset of eight of the models described in Chapter 3, Section 3.2.2 displaying angry, happy and neutral expressions. This subset included only European-American models in order to reduce heterogeneity between models within each trial display (unlike Experiments 1 and 2, the identity of the model could differ between items within a display in this experiment). The displays contained two faces presented at 177 pixels (4.5° eccentricity) to the right and left of central fixation. There were three types of display: 1) Target absent trials contained two neutral faces; 2) Single target trials contained one emotional target face (angry or happy) and one neutral face; 3) Redundant target trials contained two emotional target faces (either two angry faces or two happy faces). For all displays, the identity of the model in the left position was independent of the identity of the model in the right position (i.e., each model presented in the left position could appear with any of the eight models in the right position). See Figure 5.1A and 5.1B for an example of each type of display.

5.2.3 Design

Within-subject variables were load (one target, two targets) and target expression (angry, happy). Note that 'load' refers to the workload in each target present trial (i.e., the number of targets that need to processed in a display). Between-subject variables were self-reported anxiety and attentional control.

The dependent variables were defined as follows: a) Error rate: the percentage of trials in which an inaccurate present/absent keypress response occurred; b) Reciprocal of the RTs: the elapsed time between the onset of the display and the time at which the participant made the keypress response (for correct responses only). The reciprocal of the RTs was used to reduce the influence of outlier response times (Ratcliff, 1993); c) Processing capacity: this was quantified at the level of the hazard function of the RT distribution, which provides a measure of the capacity to complete a task at each point in time (see Section 5.2.6 for further details); d) Percentage of trials in which an eye movement occurred: defined as those trials where at least one eye movement was executed towards a target or distractor face with an amplitude greater than one degree

Figure 5.1 has been removed for copyright purposes

Figure 5.1. Example stimulus displays for each condition and an example of a trial sequence in the redundant signals task.

Note: (A) An example of a target absent display. (B) An example of: (1) a single target angry display; (2) a single target happy display; (3) a redundant target angry display; (4) a redundant target happy display. (C) An example of one trial sequence

5.2.4 Procedure

Participants completed two practice blocks of 32 trials each (one angry; one happy). This was followed by four experimental blocks of 128 trials each (two angry, two happy). The expression of the emotional face was constant within a block of trials. At the beginning of each block of trials, participants were informed whether they were searching for angry or happy faces. The rationale for blocking by expression was to ensure that participants were explicitly instructed to search for 'angry' or 'happy' faces. In contrast, it would be necessary to provide an instruction to search for 'emotional' faces if target expressions were mixed within a block of trials; under these conditions, it is likely that responses would be particularly slow in trials containing a neutral non-target due to the emotional ambiguity of these stimuli. Participants were instructed to indicate the presence or absence of at least one target emotional face in every trial display with a keypress response. The key associated with the present or absent response was counterbalanced across participants. Within each block, half of the trials were target absent and half of the trials contained at least one target. Half of the target present displays were single target trials and half were redundant target trials. The target appeared in both locations with equal frequency in the single target trials.

A trial began with a centrally-located white fixation cross, presented on a black background until the participant had fixated within one degree of the centre of the screen for 200 ms (the fixation cross was presented for a minimum duration of 1000 ms). The stimulus display was presented for 1500 ms or until a key-press response was made (whichever occurred earliest). The inter-stimulus interval was 1000 ms. See Figure 5.1C for an example of the trial sequence.

5.2.5 Data Preparation

Exclusion criteria. For the manual responses, the error rate was calculated for each condition. Following this, each false alarm RT was paired with a corresponding RT from the correct responses in present trials (this was carried out for each participant separately). These correct responses were removed from further analysis to eliminate the effect of fast guesses (Eriksen, 1988); 1.63% of the correct responses were excluded from the RT analysis on the above criteria. For the eye movement analysis, 10.48% of the trials were excluded based on the criteria described in Chapter 3, Section 3.2.5.

Participant characteristics. The mean total scores and the internal consistency for each questionnaire are provided in Table 5.1. Independent t-tests revealed that there were no significant differences between males and females in the scores on any of the questionnaires, *ts* < 2, *ns*. In the current sample, 14 participants (35%) scored equal to or more than the cut-off of 46 on the STAI-T, 4 participants (10%) scored equal to or more than the cut-off of 46 on the pre-test measure of the STAI-S, 6 participants (15%) scored equal to or more than the cut-off of 46 on the post-test measure of the STAI-S, 10 participants (25%) scored equal to or more than the cut-off of 31 on the SIAS and 12 participants (30%) scored equal to or more than the cut-off of 24 on the FNES.

The inter-correlations between the measures of individual differences and age are presented in Table 5.2. Note that Spearman's correlations were conducted with age and SIAS due to their skewed distribution; Pearson's correlations were conducted in all other cases because the scores on the remaining questionnaire measures were normally distributed. As expected, the anxiety measures were positively correlated with one another and negatively correlated with attentional control.

Table 5.1. *Descriptive statistics and internal consistency for the questionnaire measures and age.*

	M	*SD*	*Minimum (lower limit)*	*Maximum (upper limit)*	*Cronbach's α*
Trait Anxiety (STAI-T)	41.15	10.90	21 (20)	62 (80)	.93
State Anxiety (pre STAI-S)	31.50	8.23	20 (20)	49 (80)	.89
State Anxiety (post STAI-S)	32.98	9.40	20 (20)	55 (80)	.92
Social Interaction Anxiety (SIAS)	23.48	12.07	7 (0)	57 (76)	.91
Fear of Negative Evaluation (FNES)	18.18	7.64	3 (0)	29 (30)	.92
Attentional Control (ACS)	52.08	9.26	32 (20)	75 (80)	.85
Age (in years)	22.00	3.34	18	29	*na*

Table 5.2. *Inter-correlations between self-reported anxiety and attentional control measures and age.*

	1	2	3	4 [a]	5	6	7 [a]
1. Trait Anxiety (STAI-T)	-	.54***	.53***	.51**	.76***	-.46**	-.05
2. State Anxiety (pre STAI-S)		-	.69***	.45**	.39*	-.23	.07
3. State Anxiety (post STAI-S)			-	.39*	.34*	-.30†	.02
4. Social Interaction Anxiety (SIAS) [a]				-	.47**	-.42**	.03
5. Fear of Negative Evaluation (FNES)					-	-.58***	-.20
6. Attentional Control (ACS)						-	.33*
7. Age (in years) [a]							-

[a] Spearman's r_s was calculated with these variables due to their skewed distribution (Pearson's r was calculated for all other variables).

*** $p < .001$, ** $p < .01$, * $p < .05$, $^{\dagger}p < .10$

5.2.6 Data Analysis

There were three stages of data analysis. The first stage tested the basic effects associated with the redundant signals paradigm (i.e., it assessed whether there was a redundancy gain in the error rate and at the level of the mean RT). A repeated measures ANOVA was conducted to establish whether the error rate or reciprocal of the RTs were influenced by load or target expression across participants. Furthermore, the Cox Proportional Hazards Model was used to consider whether there was an effect of load or target expression on processing capacity across participants. The Cox method is a semi-parametric regression model that tests for the effects of independent variables on orderings of the hazard functions. Specifically, the Cox model outputs a hazard ratio which gives the predicted change in the hazard function with a unit change in the independent variable. 'Proportional hazards' refers to the assumption that the hazard ratio should be invariant over time. In the current study, the Schoenfeld residuals were used to consider the assumption of constant proportionality. Schoenfeld residuals represent the difference between the actual and expected effect of the independent variable. The line that best fits the plot of the Schoenfeld residuals against time should have zero slope if the effect of the independent variable is invariant over time. A stratified Cox model was used in the current study in which 'participant' was entered as a stratification variable to control for heterogeneity across participants (Allison, 1995; Therneau & Grambsch, 2000; Wenger & Gibson, 2004).

The second stage of analysis aimed to consider the cognitive mechanisms underlying enhanced threat detection in anxiety. Specifically, multiple regression analyses were conducted to consider whether anxiety or attentional control predicted the change in processing capacity associated with an increase in load (i.e. an increase from one to two targets) for the detection of threatening faces and non-threatening faces. In the context of anxiety research, using processing capacity as a dependent variable is a novel approach. Therefore, it was not considered appropriate to conduct multiple regression analyses using the forced entry method because this approach requires that there is a strong theoretical rationale for including each predictor in the regression model. Instead, a more exploratory approach was employed using stepwise regression. In this method, predictors are entered into and removed from the model on the basis of mathematical criteria. It results in the selection of the smallest set of predictors that can account for the largest proportion of the variance. Furthermore, exploratory correlations were also conducted between the change in processing capacity and the interaction term for state anxiety x trait anxiety, the interaction term for trait anxiety x attentional control and the separate attentional focusing and attentional shifting subscales of the ACS.

In the third stage of analysis and provided that there was a relationship between anxiety and threat detection, it was important to establish whether this effect occurred in the context of a broad or narrow focus of attention (as assessed by the frequency of eye movements executed in the task). Therefore, post-hoc correlations were conducted to assess whether anxiety was associated with the percentage of trials in which an eye movement occurred for each load and target expression. If anxiety is associated with a broad focus of attention, then individuals with high levels of anxiety should execute fewer eye movements.

5.3 Results

5.3.1 Basic Effects

Error rates. The mean error rate was 2.55% (SD = 2.64), 4.81% (SD = 3.28) and 3.53% (SD = 3.36) for the target absent, single target and redundant target conditions, respectively. See Table 5.3 for error rate descriptive statistics for each expression separately. This dependent variable was skewed in all conditions due to near ceiling performance in many participants and this could not be corrected by transforming the data. Therefore, the Wilcoxon signed rank test was used to consider the effect of load (one vs. two targets) for each expression separately. For angry faces, the error rate was significantly higher in the one target condition (Mdn = 3.91%) compared with the two target condition (Mdn = 2.34%), $z = 2.00$, $p < .05$, $r_w = 0.32$. For happy faces, the error rate was significantly higher in the one target condition (Mdn = 4.69%) compared with the two target condition (Mdn = 1.95%), $z = 3.28$, $p < .01$, $r_w = 0.52$. The Wilcoxon signed rank test was also used to consider the effect of expression on error rate for each load separately; there was no significant difference between the expressions in the one or two target conditions ($z < 1$, *ns*). This indicates that there was a redundancy gain in the error rate irrespective of the expression of the face (i.e. fewer errors occurred in the redundant target condition).

RT redundancy gain. A 2 (load: one target vs. two targets) by 2 (expression: angry vs. happy) repeated measures ANOVA was conducted on the reciprocal of the RTs for correct present responses. There was a main effect of load, $F(1, 39) = 102.95$, $p < .001$, where RTs were significantly faster in the two target condition (M = 0.00169, SD = 0.00020) compared with the one target condition (M = 0.00160, SD = 0.00019).

See Table 5.3 for RT descriptive statistics. The effects of expression and the interaction between expression and load were not significant, *Fs* < 2, *ns*. These results indicate that there was a redundancy gain, where an increase in load from one to two targets resulted in an increase in the overall speed of processing. This effect was observed irrespective of the expression of the target face.

Table 5.3. *Mean (+SD) for the error rates (%), reaction times (ms) and percentage of eye movement trials as a function of load and target expression.*

	Angry targets		Happy targets	
	M	*SD*	*M*	*SD*
Error rates (%)				
Target absent	2.81	3.29	2.29	2.42
Single target	4.92	4.63	4.69	3.26
Redundant target	3.96	4.88	3.09	3.16
Reaction times (ms)				
Target absent	669.61	95.48	666.04	94.69
Single target	662.32	81.82	656.86	86.11
Redundant target	626.44	74.66	615.52	80.99
Percentage of trials in which an eye movement occurred				
Target absent	66.84	34.64	66.44	34.00
Single target	71.59	32.67	69.62	33.63
Redundant target	65.73	36.28	65.91	36.78

Processing capacity. The Cox Proportional Hazards Model was used to assess the effect of load, expression and the load x expression interaction on the orderings of the hazard functions for correct present responses only. Figure 5.2 shows the plots of the Schoenfeld residuals against RTs for load and expression separately. The residuals fall into two distinct groups on either side of zero because load (one target vs. two targets) and expression (angry vs. happy) were both dichotomous variables. Figure 5.2 also shows the best fitting regression lines, which should have zero slope if the assumption of constant proportionality is satisfied. The graph indicates that the regression line for load has a negative slope. A regression analysis in which RT was entered as the predictor and the residuals for load were entered as the dependent variable revealed that the slope of the line was significantly different from zero, $F(1, 9812) = 24.11$, $p < .001$. By examining Figure 5.2 and conducting tests for non-zero slopes (i.e. further regression analyses), it became apparent that the departure from constant proportionality occurred for the very shortest (< 400 ms) and the very longest (> 725 ms) RTs in the sample. Therefore, the residuals for load were regressed against RT between 400 and 725 ms and the slope of the regression line did not significantly differ from zero, $F < 1$, *ns*. That is, the assumption of constant proportionality was satisfied between 400 and 725 ms.

Figure 5.2 shows that the best fitting regression line for expression had a near zero slope. Regression analyses in which RT was entered as the predictor and the Schoenfeld residuals for expression were entered as the dependent variable revealed that the slope of the line did not significantly differ from zero for the entire RT distribution or for the censored 400-725 ms time interval, *Fs* < 2.5, *ns.* See Wenger and Gibson (2004) for a similar treatment of the Schoenfeld residuals. In all of the following analyses, the RT distribution was right and left censored from 400-725 ms; this region of the RT distribution included 77.69% of the correct responses in the target present trials.

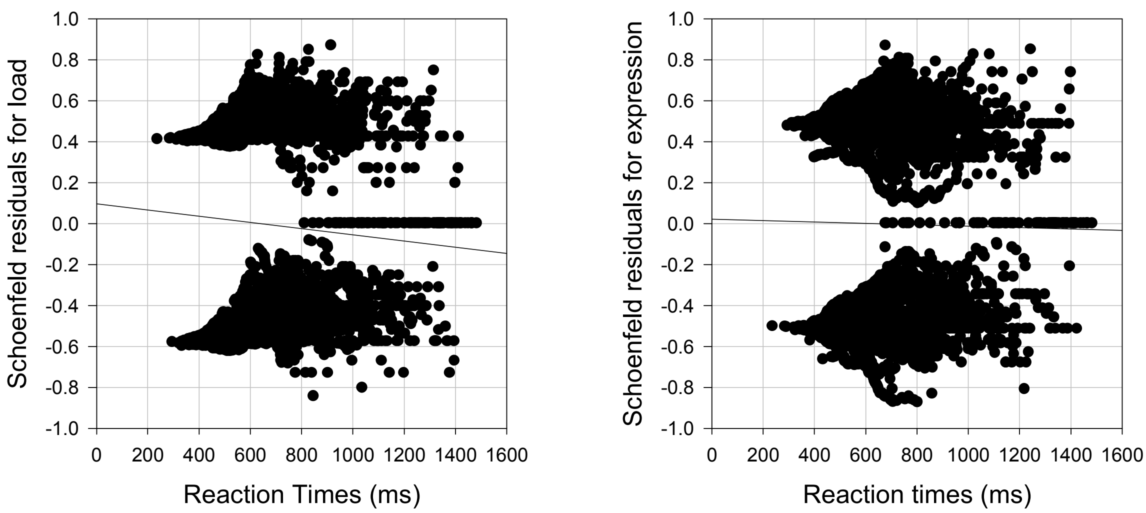

Figure 5.2. Schoenfeld residuals for load (left) and expression (right) as a function of reaction times.

The analysis using the Cox Proportional Hazards Model was conducted for RTs between 400 and 725 ms with load, target expression, and the load x expression interaction as predictors. The results indicated that load was a significant predictor of processing capacity at the level of the hazard function of the RT distribution, $\chi^2(1) = 14.46$, $p < .001$ (see Table 5.4). Specifically, the hazard ratio revealed that the magnitude of the hazard for two targets was 1.32 times that for one target across the censored time period. In other words, target redundancy resulted in an overall 32% increase in processing capacity. There was a trend towards expression significantly predicting processing capacity, $\chi^2(1) = 3.25$, $p = .072$. The hazard ratio revealed that the magnitude of the hazard for happy faces was 1.15 times greater than that for the angry faces. There was a 15% increase in processing capacity for happy (vs. angry) faces. Table 5.4 also shows that the load x expression interaction was not a significant predictor of processing capacity.

Table 5.4. *Results of fitting the proportional hazards model to the left- and right-censored RT data, stratifying across participants.*

Predictor	*df*	β	*SE*	χ^2	*% change*
Load (L)	1	0.28	0.07	14.46	32***
Expression (E)	1	0.14	0.07	3.25	$15^{\dagger}$
L x E	1	-0.05	0.05	1.15	-4.9

*** $p < .001$, $^{\dagger}p < .10$

5.3.2 Processing Capacity and Anxiety.

The following analysis assessed whether anxiety or attentional control predicted the change in processing capacity associated with an increase in load from one to two targets. Cox's proportional hazards model was applied to each participant and each expression separately with load entered as the independent variable. This provided a beta estimate of the change in capacity associated with an increase in load for each participant and each expression. These beta estimates were regressed onto the six predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety, fear of negative evaluation, attentional control). For the happy faces, there were no significant predictors of the change in capacity as a function of load. In contrast, for the angry faces, trait anxiety was a significant predictor of capacity changes due to an increase in load ($\beta = 0.195$, $R^2 = 0.57$, $p < .05$, see Figure 5.3). Note that none of the other five variables significantly predicted capacity changes for the angry faces.

Thus, the increase in processing capacity associated with the addition of a redundant angry target was greater in individuals with high levels of trait anxiety. In other words, less work was required to detect angry faces in the presence of multiple (vs. single) targets and the magnitude of this effect increased with increasing trait anxiety. In contrast, there was no effect of anxiety or attentional control on the increase in processing capacity associated with the addition of a redundant happy target.

Exploratory correlations showed that there was no relationship between the interaction terms (pre state anxiety x trait anxiety, post state anxiety x trait anxiety or attentional control x trait anxiety) and the change in processing capacity as a function of load for either expression. Therefore, the effect of trait anxiety was not specific to individuals with high levels of state anxiety or low levels of attentional control. Pearson's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the change in processing capacity as a function of load were also non significant for each expression, *ps* > .10, *ns*.

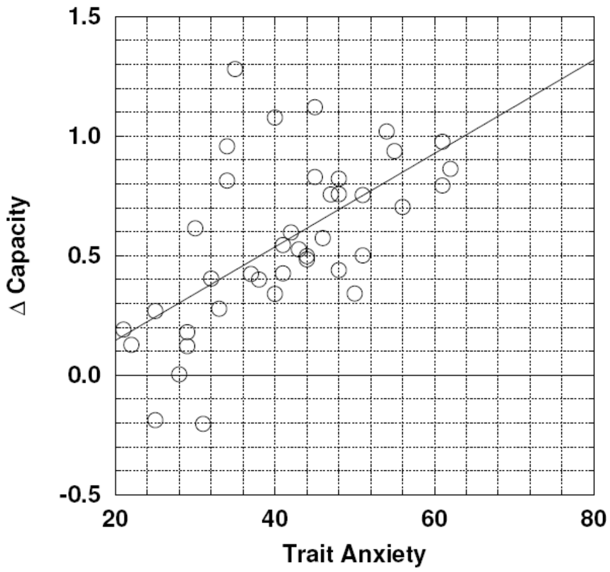

Figure 5.3. Change in capacity (due to an increase in load) as a function of trait anxiety for angry faces.

Note. ΔCapacity values are the predicted change in the hazard function with an increase in load. ΔCapacity values greater than 0 indicate that processing capacity increased with an increase in load from one to two targets. ΔCapacity values less than 0 indicate that processing capacity decreased with an increase in load from one to two targets.

5.3.3 Eye movements and Trait Anxiety

Table 5.3 presents the mean percentage of trials in which an eye movement occurred for each condition. The table indicates that eye movements were not necessary to acquire information about the presence or absence of a target (i.e., the eyes remained still on up to 35% of the trials). In order to provide further insight into the relationship between trait anxiety and processing capacity, it was important to establish whether the effect occurred in the context of a broad or narrow focus of attention. Therefore, eye movements were analysed to consider whether trait anxiety was associated with the percentage of trials in which an eye movement occurred. It was important to conduct this analysis for every experimental condition because it was unclear whether any relationship between trait anxiety and eye movements would occur across conditions or whether it would be specific to trials containing angry targets. It was not appropriate to conduct regression analyses on the eye movement data because there was a violation of the assumption of normally distributed residuals. Spearman correlations were conducted between scores on the STAI-T and the percentage of eye movement trials, considering each target condition (target absent, single target, redundant target) and each expression separately. For trials containing angry target faces, there were significant negative correlations between trait anxiety and the percentage of eye movement trials for each load, $r_s < -.38$, $ps < .05$. This effect was also observed in trials containing happy target faces for each load, $r_s < -.36$, $ps < .05$ and for target absent trials in the angry and happy experimental blocks, $r_s < -.39$, $ps < .05$. Thus, higher levels of trait anxiety were associated with fewer eye movements in all experimental conditions (see Figure 5.4).

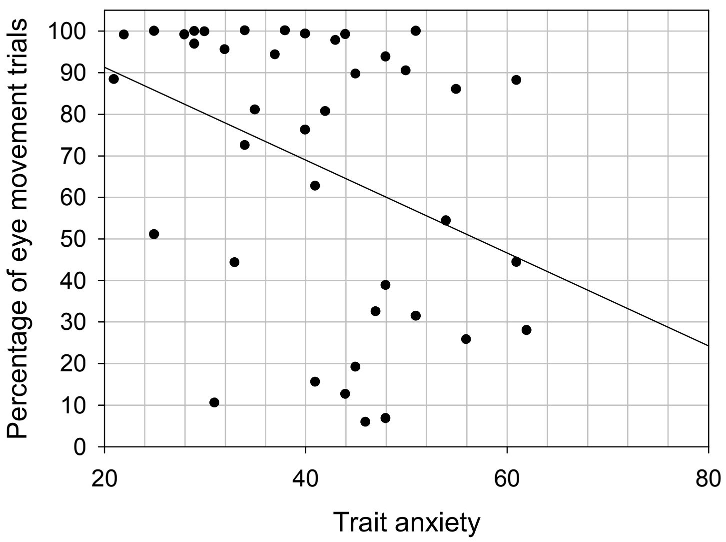

Figure 5.4. The mean percentage of trials in which an eye movement occurred as a function of trait anxiety (collapsed across all experimental conditions).

5.4 Discussion

The present study considered the cognitive mechanisms and attentional processes underlying threat detection in anxiety. It explored the possibility that, prior to threat detection, anxiety is associated with an increased ability to integrate threats from multiple locations across the visual field within a broad focus of attention. It also considered the alternative possibility that anxiety is associated with excessively scanning the environment with a narrow focus of attention prior to threat detection.

The present study found that there was a redundancy gain; participants were faster and more accurate at detecting a target in the redundant target condition compared with the single target condition. Furthermore, there was a 32% increase in processing capacity in the redundant target condition compared with the single target condition. Thus, target redundancy was associated with an increase in the speed of processing at the level of the mean RT and an increase in processing capacity at the level of the RT distribution, irrespective of the expression of the target. These finding are consistent with previous work using the redundant signals paradigm (Grice & Canham, 1990; Miller, 1982; Müller et al., 1994; Zehetleitner et al., 2008). In particular, the finding of increased processing capacity to detect multiple (vs. single) emotional faces is consistent with previous research reporting co-active processing in the perception of emotional expressions. Tamietto et al. (2006, 2007) reported a violation of the race model inequality (i.e. evidence of co-activation) when two (vs. one) emotional faces were presented. One limitation associated with the race model inequality is that it can only be used to detect co-activation at very early time points. In contrast, measures of processing capacity can be used across the entire RT distribution. Therefore, the processing capacity measures used in this experiment extend the findings from the Tamietto et al. (2006, 2007) studies to indicate that co-active processing occurred for a substantial portion of the RT distribution.

The results also highlighted that trait anxiety was associated with increased processing capacity to detect multiple (vs. single) threats. This finding suggests that there is increasing efficiency in detecting threat as the number of threats in the environment increases in individuals with high levels of anxiety. A further finding was that high trait anxious individuals executed fewer eye movements and this effect was observed irrespective of the presence or absence, number and expression of the target face. This finding is consistent with the proposition of hypervigilance in anxiety. It suggests that anxious individuals keep their eyes still in order to allocate attentional resources widely across the visual field. It is interesting to note that this tendency to keep the eyes still was adopted by anxious individuals irrespective of whether they were asked to detect the presence of angry or happy faces. This raises the possibility that the default strategy in anxiety is to maintain a broad focus of attention even in the absence of threat. The long-term purpose of this strategy would be to facilitate the detection of threatening or potentially threatening stimuli in multiple locations across the visual field and to minimise the potential danger associated with focusing attention on one object or location (see Eysenck et al., 2007). Taken together, the finding that trait anxiety was associated with increased processing capacity and fewer eye movements suggests that anxious individuals can distribute attentional resources widely to facilitate threat detection even when the threatening stimuli are presented outside foveal vision.

The present findings are consistent with previous research highlighting enhanced detection of singleton threat (Byrne & Eysenck, 1995; Matsumoto, 2010), a broad focus of attention and an increased ability to detect or locate peripheral stimuli (e.g., Keogh & French, 1999) in anxiety. In line with previous research, there was no evidence to suggest that anxious individuals excessively scan the visual environment (Freeman et al., 2000). The current findings extend this previous work by providing an explanation for how anxiety affects threat detection and highlighting the conditions in which a broad focus of attention is particularly likely to facilitate threat detection. Specifically, this study raises the possibility that enhanced threat detection in anxiety occurs in the context of a broad focus of attention, which allows information from multiple threats to be integrated via co-activation from across the visual field such that responses to the presence of multiple threats are faster than to a single threat. The integration of threatening information means that less work is required to detect the presence of threat when it occurs in multiple locations. While previous research indicates that a broad focus of attention leads to greater distractibility and poor attentional control (Eysenck et al., 2007), the current study emphasises the beneficial effects of this strategy on threat detection. However, while a broad focus of attention was an optimal strategy for threat detection in the current study, it remains possible that scanning the environment with a narrow focus of attention and rapid eye movements would be a beneficial strategy for threat detection under different experimental conditions (i.e., when there are more than two stimuli). Therefore, the parameters of the relationship between distributed attention and co-active threat detection in anxiety require further research (see Section 7.5).

It has been argued that data consistent with super-capacity processing can occur in a parallel (Eidels, Townsend, & Pomerantz, 2008; Townsend, 1990) or serial exhaustive (Townsend & Nozawa, 1997) processing architecture and need not be produced by a co-active processing architecture. These alternative interpretations require that the increase in processing capacity in the redundant target condition is due to the absence of the non-target rather than co-activation between the targets. In other words, the non-targets slow performance on the single target trials and the level of interference depends on factors such as target-distractor similarity (Eidels et al., 2008). The current study cannot definitively determine whether the relationship between trait anxiety and increased processing capacity to detect threat occurs as a result of co-activation of threat signals in the redundant target trials or slowed processing of the non-target in the single target trials. However, there are reasons to favour the former interpretation. In the context of the present findings, the parallel or serial-exhaustive interpretations would imply that increasing anxiety is associated with decreasing capacity to detect threat in the single target trials due to interference from the neutral non-targets. This is inconsistent with previous research indicating that anxious individuals detect threatening faces (presented amongst neutral distractors) with greater efficiency than non-anxious individuals (Byrne & Eysenck, 1995; Matsumoto, 2010). From a theoretical perspective, this interpretation is also inconsistent with conceptual frameworks of anxiety and attention, which suggest that trait anxiety is characterised by the rapid detection of threat (see Eysenck, 1991, 1992).

Furthermore, the interactive race model (Mordkoff & Yantis, 1991) suggests that data consistent with co-activation can occur in a parallel processing architecture that allows inter-channel crosstalk. Interactive race models state that target processing is carried out in parallel on independent channels in the redundant target condition, where the first channel to complete this processing wins the race and determines the response. In this respect, interactive race models are identical to independent race models. However, the interactive race models also allow for the exchange of information between the channels. It is important to note that, despite this inter-channel crosstalk, decisions on the presence of the target are carried out separately on the two channels. In contrast, co-activation models suggest that target signals are pooled prior to a decision about the presence of a target. Mordkoff and Yantis (1991) argued that inter-channel crosstalk can produce findings consistent with co-activation if the identity of an item on one channel provides probabilistic information about the identity of the item on the other channel.

Given the design of the current study, it is possible that inter-channel crosstalk occurred between the channels. Specifically, 50% of the trials were target absent, 12.5% of the trials were single target left, 12.5% of the trials were single target right and 25% of the trials were redundant target. Therefore, if a non-target appeared in the left position, then probabilistic evidence would indicate that it was more likely that the right position would contain a non-target compared with a target. Similarly, if a target appeared in the left position, then probabilistic evidence would indicate that it was more likely that the right position would contain a target compared with a non-target. According to Mordkoff and Yantis (1991), these particular inter-stimulus contingencies could lead to the inhibition of target identification in the single target trials and the facilitation of target identification in the redundant target trials. Although this interpretation is logically possible, it is highly unlikely that it can account for the relationship between trait anxiety and processing capacity. The inter-stimulus contingencies were identical in the angry and happy blocks and, therefore, the relationship between trait anxiety and processing capacity would have occurred for both target expressions if the effect was driven by inter-channel crosstalk. Therefore, a co-activation model remains the most likely explanation for the relationship between trait anxiety and increased processing capacity to detect threat.

In summary, the findings from this study raise the possibility that anxiety affects the efficiency of a co-active threat detection system, where this is likely to arise as a consequence of increased sensitivity to threat and a broad focus of attention. This informs current theoretical models to suggest that neither attentional focusing (Mogg & Bradley, 1998) nor lowered attentional control (Eysenck et al., 2007) provide a comprehensive account of the relationship between anxiety and attention.

Moreover, to summarise the findings presented thus far, Experiments 1 and 2 found no evidence to suggest that anxiety was characterised by selective attention to threat in orienting responses. Instead, Experiments 2 and 3 highlighted that anxiety is associated with a broad focus of attention that leads to distractibility by task-irrelevant threat and enhanced threat detection. These findings raise a further question that lies in stark contrast to theories of selective attention to threat in anxiety. It seems possible that a broad focus of attention in anxiety may actually be associated with difficulties in localising and focusing attention on an individual threat when there are multiple threats in the environment. Specifically, anxious individuals may regard it as potentially dangerous to narrow attention onto one threat when it is known that additional threats are present in other locations. This is considered in the following experiment.

Chapter 6 : Anxiety and Processing Capacity for Threat Localisation

6.1 Introduction

The aim of the current study was to revisit and extend each of the questions raised in the previous empirical experiments using a localisation version of the redundant signals paradigm. This paradigm was used to assess the hypothesis that the tendency to maintain a broad focus of attention in anxiety would adversely affect the localisation of individual threats when multiple threats are present in the visual environment. This can be regarded as an adaptive response because it ensures that all sources of threat are monitored (i.e., an angry crowd) and avoids the potential danger associated with focusing attention on a single threat (i.e. an angry individual) when multiple threats are known to be present.

A recent study used a localisation version of the redundant signals paradigm to consider the latency of initiating an eye movement to a single target in displays containing one or two targets (Nelson & Hughes, 2007). Nelson and Hughes (2007) highlighted that two types of saccades occur when participants are presented with multiple targets and asked to look at one of them as quickly as possible: averaging saccades and bistable saccades. Averaging saccades land in an intermediate location between the targets and are proposed to occur when activation from each target is pooled prior to the saccadic response. Bistable saccades land on one of the targets; in order to execute a saccade to one target it is necessary to resolve the response conflict between multiple saccade programs by inhibiting activation from the other competing targets (i.e. similar to the remote distractor effect; Walker et al., 1997).

Nelson and Hughes (2007) aimed to identify the processing architectures underlying averaging and bistable saccades. They predicted that, in the presence of multiple targets, saccade latencies would be shorter for averaging saccades compared with bistable saccades due to the sensory pooling of target activation. Furthermore, they suggested that sensory pooling on averaging saccades would lead to a violation of the race model inequality when comparing single and multiple targets (i.e. co-activation). In contrast, they suggested that lateral inhibition (i.e., where neural activity in one region suppresses neural activity in another region) and response conflict occur in the execution of bistable saccades; this should lead to slowed performance in the multiple (vs. single) target condition. They instructed participants to execute an eye movement to a single target as quickly and accurately as possible in displays containing one or two targets. Their results indicated that the first saccade latency was longer in the redundant target condition compared with the single target condition. Furthermore, they found that there were substantial violations of the Grice inequality, which indicates that redundant target performance was slower than would be predicted by a race model (i.e., very limited capacity processing). These findings were observed for averaging and bistable saccades and Nelson and Hughes (2007) concluded that both types of saccades were initiated within the same processing architecture. Specifically, they suggested that their results were compatible with a parallel processing architecture in which there was very limited capacity due to response competition and inhibitory interactions between competing saccade programs. They found no evidence to support the notion that averaging saccades were initiated within a co-active processing architecture.

Thus, the existing literature indicates that target redundancy may have distinct effects on detection responses (Miller, 1982) and localisation responses (Nelson & Hughes, 2007); redundancy facilitates target detection and impairs target localisation. These differences are likely to exist because multiple target signals provide converging evidence about the presence of a target in a detection task, whereas multiple target signals provide conflicting information about the location of a target in a localisation task.

The current study used a localisation version of the redundant signals paradigm from Experiment 3. Participants were asked to look at (i.e. initiate an eye movement towards) a threatening or non-threatening target face as quickly and accurately as possible in displays containing one or two targets. The principal aim of the study was to consider the relationship between anxiety and the ability to locate and focus attention on an individual threat when multiple threats are present in the environment. In line with previous eye movement findings (Nelson & Hughes, 2007), it was predicted that redundant targets would delay saccadic responses across participants due to inhibitory interactions between the two target signals. If this were the case, then target redundancy would be associated with decreased processing capacity to locate the target; specifically, the work required to generate and execute a saccade would be greater in the redundant target condition compared with the single target condition because, in the former case, additional processing would be needed to resolve the response conflict between the two targets.

In relation to anxiety, it was predicted that the delay in locating the target and the decrease in processing capacity in the redundant (vs. single) target condition would be greater for anxious individuals when locating threat. This prediction was based on the results from the previous experiments, which indicated that individuals with high levels of anxiety maintain a broad focus of attention (Experiment 3) rather than orienting to singleton threat with high speed and accuracy (Experiment 1). This broad focus of attention allows anxious individuals to acquire and co-activate information about the presence of threat from across the visual field, thus enhancing threat detection (Experiment 3). In the current study, it was predicted that, in addition to acquiring information about the presence of multiple threats, the tendency to maintain a broad focus of attention would also allow anxious individuals to acquire conflicting information about the possible location of multiple threats across the visual field. Given that anxiety is associated with difficulties inhibiting threat processing (Experiment 2), it was predicted that anxious individuals would demonstrate a reduced ability to inhibit the processing of a redundant threat in order to execute a saccade to another threat. This impairment in the localisation of singleton threat would further demonstrate that individuals with high levels of anxiety are inclined to monitor for multiple threats within a broad attentional beam rather than allocating attentional resources to a specific location.

6.2 Method

6.2.1 Participants

Thirty-six healthy adults participated in the experiment (*mean age* = 24.72 years, *SD* = 2.94, *range* = 19-30 years; 8 males).

6.2.2 Stimuli

The faces used in this experiment were identical to those faces used in Experiment 3. The displays contained two faces presented at 177 pixels (4.5° eccentricity) to the right and left of central fixation. There were two types of display: 1) Single target trials contained one emotional target face (angry or happy) and one neutral face; 2) Redundant target trials contained two emotional target faces (either two angry faces or two happy faces). The single target and redundant target displays used in the current study were identical to those used in Experiment 3. See Figure 6.1A for an example of each type of display.

Figure 6.1 has been removed for copyright purposes

Figure 6.1. Example stimulus displays for each condition and an example of a trial sequence in the localisation version of the redundant signals task.

Note: (A) An example of: (1) a single target angry display; (2) a single target happy display; (3) a redundant target angry display; (4) a redundant target happy display. (B) An example of one trial sequence.

6.2.3 Design

Within-subject variables were load (one target, two targets) and target expression (angry, happy). Between-subject variables were self-reported anxiety and attentional control.

The dependent variables were: a) Percentage of accurate first saccades in the single target trials: accurate saccades were defined as those that landed on or within one degree of the target; b) The reciprocal of the latency of accurate first saccades[2]: first saccade latencies were the elapsed time between the onset of the display and the initiation of the first saccade; c) Processing capacity: this was quantified at the level of the hazard function of the latency distribution, which provides a measure of the capacity to initiate a saccade to the target at each point in time.

6.2.4 Procedure

Participants completed two practice blocks of 32 trials each (one angry; one happy). This was followed by four experimental blocks of 128 trials each (two angry, two happy). The expression of the emotional face was constant within a block of trials. At the beginning of each block of trials, participants were informed whether they were searching for angry or happy faces. The rationale for blocking by expression was identical to the previous experiment (see Section 5.2.4). Participants were instructed to look at a target emotional face as quickly and accurately as possible in every trial display. Participants were informed that it was sufficient to look at one face in displays containing two targets.

Within each block, half of the displays were single target trials and half were redundant target trials. The target appeared in both locations with equal frequency in the single target trials. A trial began with a centrally-located white fixation cross, presented on a black background until the participant had fixated within one degree of the centre of the screen for 200 ms (the fixation cross was presented for a minimum

[2] Note that, for consistency with Experiment 3, the reciprocal of the first saccade latency was used to reduce the influence of outlier responses in all analyses at the level of the mean. This is not a traditional approach to use in the analysis of eye movement data. In contrast, outlier responses were defined as first saccade latencies above or below 3 standard deviations from the mean in Experiment 1 and Experiment 2; these outlier responses were removed from the analysis. This approach of removing very short and very long latencies based on standard deviations is not appropriate in the current study because these outlier responses need to be included in the analysis of the latency distribution. However, in order to check that these methods of dealing with outliers led to converging results, the mean first saccade analyses were repeated on the raw latencies (i.e., with no reciprocal transformation) and outlier responses were removed based on the 3 standard deviation cut-off. All of the results reported in Section 6.3 related to the mean first saccade latency were replicated when outliers were removed from the analysis.

duration of 1000 ms). The stimulus display was presented for 1000 ms. The inter-stimulus interval was 1000 ms. See Figure 6.1B for an example of the trial sequence.

6.2.5 Data Preparation

Exclusion criteria. Based on the eye movement exclusion criteria outlined in Chapter 3, Section 3.2.5, 6.04% of the trials were excluded from the analysis. In 0.57% of the trials, the amplitude of the initial saccade was smaller than 1 degree; in these cases the initial saccade was removed and replaced by the subsequent saccade. The percentage of accurate first saccades was calculated for each single target condition. Following this, each inaccurate first saccade from the single target trials was matched for latency with a trial from the redundant target condition (for each participant). These redundant target trials were removed from further analysis to eliminate the effect of fast guesses (Eriksen, 1988); 37.07% of the redundant target trials were excluded on the above criteria[3].

Participant characteristics. The mean total scores and the internal consistency for each questionnaire are provided in Table 6.1. There was one outlier on the post-test state anxiety scale. The removal of this outlier did not affect any of the results or conclusions reported below and, therefore, this participant was retained in all analyses. Independent t-tests revealed that there were no significant differences between males and females in the scores on any of the questionnaires, *ts* < 1.5, *ns*.

In the current sample, 8 participants (22%) scored equal to or more than 46 on the STAI-T, 3 participants (8%) scored equal to or more than 46 on the pre-test measure of the STAI-S, 2 participants (6%) scored equal to or more than 46 on the post-test measure of the STAI-S, 4 participants (8%) scored equal to or more than 31 on the SIAS and 8 participants (22%) scored equal to or more than 24 on the FNES.

The inter-correlations between the measures of individual differences and age are presented in Table 6.2. Note that Spearman's correlations were conducted with post STAI-S and SIAS due to their skewed distribution; Pearson's correlations were conducted in all other cases because the remaining variables were normally distributed. As with the previous studies, the measures of anxiety were positively correlated with one another. In contrast with predictions and the findings from the previous studies, the correlations between attentional control and the measures of anxiety were non-significant in this study

[3] Note that a further 0.3% of the redundant target trials were removed from the analysis because first saccades did not land within one degree of a target face.

Table 6.1. *Descriptive statistics and internal consistency for the questionnaire measures and age.*

	M	*SD*	*Minimum (lower limit)*	*Maximum (upper limit)*	*Cronbach's α*
Trait Anxiety (STAI-T)	38.44	9.34	22 (20)	57 (80)	.92
State Anxiety (pre STAI-S)	31.06	8.21	20 (20)	50 (80)	.90
State Anxiety (post STAI-S)	31.19	8.84	20 (20)	59 (80)	.91
Social Interaction Anxiety (SIAS)	17.03	10.39	5 (0)	48 (76)	.92
Fear of Negative Evaluation (FNES)	15.36	7.73	0 (0)	28 (30)	.92
Attentional Control (ACS)	53.97	6.21	38 (20)	68 (80)	.75
Age (years)	24.72	2.94	19	30	*na*

Table 6.2. *Inter-correlations between self-reported anxiety and attentional control measures and age*

	1	2	3 [a]	4 [a]	5	6	7
1. Trait Anxiety (STAI-T)	-	.56***	.60***	.70***	.65***	-.24	-.25
2. State Anxiety (pre STAI-S)		-	.71***	.41*	.49**	-.20	-.34*
3. State Anxiety (post STAI-S) [a]			-	.49**	.41*	-.07	-.27
4. Social Interaction Anxiety (SIAS) [a]				-	.48**	-.05	-.28
5. Fear of Negative Evaluation (FNES)					-	-.04	-.10
6. Attentional Control (ACS)						-	.20
7. Age (in years)							-

[a] Spearman's r_s was calculated with these variables due to their skewed distribution (Pearson's r was calculated for all other variables).

*** $p < .001$, ** $p < .01$, * $p < .05$, $^{\dagger}p < .10$

6.2.6 Data Analysis

The first stage of data analysis tested the basic effects associated with the localisation version of the redundant signals paradigm. The accuracy of the first saccade was considered in the single target trials. Furthermore, a repeated measures ANOVA was conducted to establish whether target redundancy or target expression affected the mean first saccade latencies to the target. The Cox Proportional Hazards Model (stratified by participant) was used to consider whether target redundancy or target expression affected processing capacity (i.e. work done) to initiate a saccade to the target. The Schoenfeld residuals were assessed to consider the assumption of constant proportionality in the Cox Proportional Hazards Model.

Secondly, as a point of comparison and extension to the visual search study in Experiment 1, multiple regression analyses were conducted to consider whether anxiety or attentional control predicted the mean latency or the accuracy of localising threatening and non-threatening faces in the single and redundant target trials separately. A forced entry regression method was used in which the six predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety, fear of negative evaluation and attentional control) were entered into the regression model simultaneously. This method was used to ensure that the analysis in the current study was directly comparable to the analysis in the visual search study (Experiment 1). The requirement to look at the emotional face in the single target trials was analogous to the requirement to look at the upright face in the two-parafoveal displays in the visual search study (the eccentricity and position of the two faces was identical across the two experiments). Therefore, it was predicted that the relationship between anxiety and threat localisation in the single target trials would replicate the findings from Experiment 1. However, it was predicted that anxiety would be associated with slower localisation of threat in the redundant target trials.

As a comparison and extension to the detection version of the redundant signals paradigm (Experiment 3), the third stage of analysis assessed whether individual differences in anxiety or attentional control were associated with decreased processing capacity to initiate a saccade to the target at the level of the latency distribution for multiple (vs. single) threatening faces. Specifically, multiple regression analyses were conducted to consider whether anxiety or attentional control predicted processing capacity as a function of load for threatening and non-threatening faces. A stepwise regression procedure was used in which the six predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety, fear of negative evaluation and attentional control) were entered and removed from the model based on mathematical criteria. This stepwise method was used to ensure that the analysis in the current study was directly comparable to the analysis conducted in the RT redundant signals study.

Finally, exploratory correlations were conducted between the dependent variables and the interaction term for state anxiety x trait anxiety (for the pre- and post-test measures of state anxiety separately), the interaction term for trait anxiety x attentional control and the separate attentional focusing and attentional shifting subscales of the ACS.

6.3 Results

6.3.1 Basic Effects

Accuracy. A paired samples t-test was conducted on the percentage of accurate first saccades in the single target trials. There was a trend towards a main effect of expression, $t(34) = 2.01$, $p = .053$, $d = 0.18$, where the percentage of accurate first saccades was greater for angry target faces ($M = 63.08$, $SD = 11.84$) compared with happy target faces ($M = 61.04$, SD = 10.53).

Latency of accurate first saccades. After correcting for fast guesses, a 2 (load) by 2 (expression) repeated measures ANOVA was conducted on the reciprocal of the accurate first saccade latencies. There were no significant main effects or interactions, all *Fs* < 1, *ns*. Thus, target redundancy neither had an adverse effect on target localisation nor did it result in a redundancy gain. See Table 6.3 for descriptive statistics on the first saccade latencies in each experimental condition.

Table 6.3. *Mean (+SD) for accurate first saccade latencies (in ms) as a function of load and target expression.*

	Angry targets		Happy targets	
	M	*SD*	*M*	*SD*
Single target	243.75	69.61	240.47	67.27
Redundant target	247.78	76.52	244.33	70.37

Processing capacity. After correcting for fast guesses, the Cox Proportional Hazards Model was used to assess the effect of load, expression and the load x expression interaction on the orderings of the hazard functions for accurate first saccades only. Figure 6.2 shows the plots of the Schoenfeld residuals against first saccade latency for load and expression separately. This figure indicates that the best fitting regression line for the Schoenfeld residuals for load has a negative slope. A regression analysis in which latency was entered as the predictor and the Schoenfeld residuals for load were entered as the dependent variable revealed that the slope of the line was significantly different from zero, $F(1, 10807) = 31.18$, $p < .001$. Thus, the assumption of constant proportionality was not satisfied across the entire latency distribution. Tests for non-zero slopes and an examination of Figure 6.2 indicated that the departure from constant proportionality occurred for the very shortest (< 100 ms) and the very longest (> 280 ms) latencies in the sample. Therefore, the residuals for load were regressed against latency between 100 and 280 ms and the slope of the regression line did not significantly differ from zero, $F < 3.5$, $p > .05$. This indicates that the assumption of constant proportionality was satisfied between 100 and 280 ms.

Figure 6.2 also shows the Schoenfeld residuals for expression across the latency distribution and reveals that the best fitting regression line had a near zero slope. Regression analyses in which latency was entered as the predictor and the Schoenfeld residuals for expression were entered as the dependent variable revealed that the slope of the line did not significantly differ from zero for the entire latency distribution or for the censored 100-280 ms time interval, $Fs < 2.5$, *ns*. In all of the following analyses, the latency distribution was right and left censored from 100-280 ms; this region of the latency distribution included 72.98% of the accurate first saccades.

The analysis using the Cox Proportional Hazards Model was conducted for accurate first saccade latencies between 100 and 280 ms with load, target expression, and the load x expression interaction as predictors. Table 6.4 shows that there were no significant predictors of processing capacity. Target redundancy did not result in a decrease (or increase) in processing capacity to locate the target irrespective of the expression of the target face.

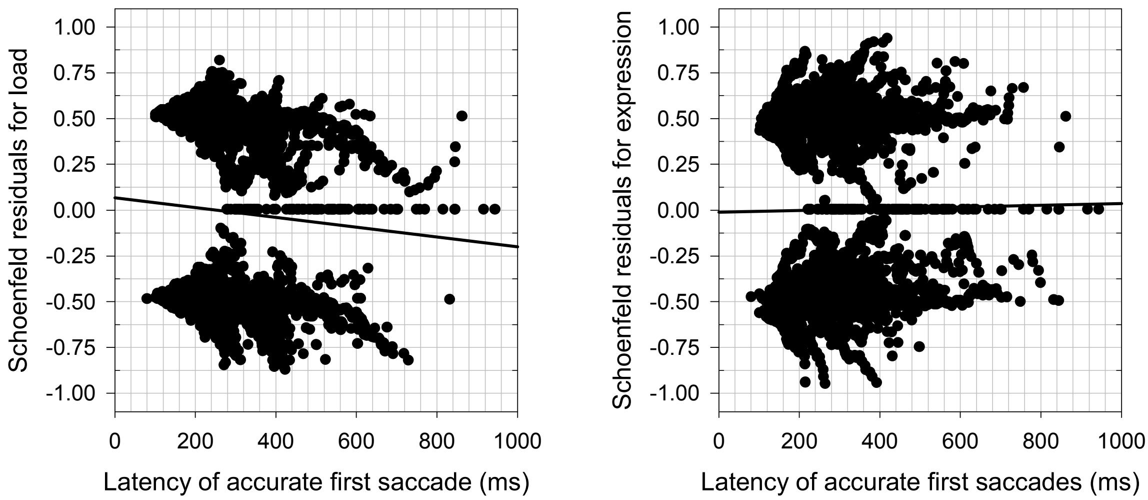

Figure 6.2. Schoenfeld residuals for load (left) and expression (right) as a function of the latency of the accurate first saccades.

Table 6.4. *Results of fitting the proportional hazards model to the left- and right-censored first saccade latency data, stratifying across participants.*

Predictor	*df*	*B*	*SE*	χ^2	*% change*
Load (L)	1	0.10	0.06	2.37	10
Expression (E)	1	-0.01	0.07	0.02	-1
L x E	1	0.02	0.04	0.15	1.5

*** $p < .001$, ** $p < .01$, * $p < .05$, $^{\dagger}p < .10$

6.3.2 Localisation Performance and Anxiety

The following analysis considered whether anxiety or attentional control were associated with the speed or accuracy of locating angry (and happy) faces in displays containing single or multiple targets. The percentage of accurate first saccades in the single target trials was regressed against the six predictors (trait anxiety, state anxiety (pre-test), state anxiety (post-test), social interaction anxiety, fear of negative evaluation and attentional control) for each expression separately. The regression models were not significant for either expression, R^2s < .05, *F*s < 1, *ns* and there were no significant predictors within the models, $|\beta s| < .22$, *p*s > .10. The reciprocal of the latency was regressed against the six predictors for each load and each expression separately. The regression models were not significant for either load or either expression, R^2s < .07, *F*s < 1, *ns* and there were no significant predictors within the models $|\beta s| < .26$, *p*s > .10.

Furthermore, exploratory correlations showed that there was no relationship between the interaction terms (pre state anxiety x trait anxiety, post state anxiety x trait anxiety or trait anxiety x attentional control) and the speed or accuracy of localisation responses for angry or happy faces in the presence of single or multiple targets, *ps* > .10, *ns*. The speed and accuracy of localisation were also unrelated to scores on the attentional focusing and attentional shifting subscales of the ACS for all conditions, *ps* > .10, *ns*.

6.3.3 Processing Capacity and Anxiety

The following analysis assessed whether anxiety or attentional control predicted the change in processing capacity associated with an increase in load from one to two targets. Cox's proportional hazards model was applied to each participant and each expression separately with load entered as the independent variable. This provided a beta estimate of the change in capacity associated with an increase in load for each participant and each expression. These beta estimates were regressed onto the six anxiety and attentional control predictors for angry and happy faces separately. The results indicated that no variables reached statistical criterion for entry into the regression model for either expression and, therefore, there were no significant predictors of the change in capacity as a function of load for angry or happy faces. Furthermore, exploratory correlations showed that there was no relationship between the interaction terms (pre state anxiety x trait anxiety, post state anxiety x trait anxiety or attentional control x trait anxiety) and the change in processing capacity as a function of load for either expression, *ps* > .10, *ns*. Pearson's correlations between the separate attentional control subscales (attentional shifting and attentional focusing) and the change in capacity were also non significant for each expression, *ps* > .10, *ns*.

6.4 Discussion

The current study utilised a localisation version of the redundant signals paradigm to consider the relationship between anxiety and the ability to locate an individual threat when multiple threats are present in the environment. It was predicted that anxious individuals would find it difficult to focus attention on one threat when there was an additional threat in a separate location. Specifically, it was predicted that the conflicting information from multiple threats would lead to greater interference in individuals with high levels of anxiety due to their inability to inhibit threat processing.

Contrary to these predictions, anxiety was unrelated to the localisation of threatening faces regardless of whether single or multiple threats were presented. In line with the visual search experiment (Experiment 1), there was no evidence to suggest that anxious individuals were quicker or more accurate in orienting towards singleton threats. More importantly in this study, anxiety neither influenced the speed of locating an angry face in the presence of multiple threats nor did it affect processing capacity to locate threat in the presence of multiple (vs. single) targets.

These results extend the findings from the remote distractor paradigm (Experiment 2) to suggest that there are only particular experimental conditions in which anxiety is associated with an inability to inhibit processing of one threatening stimulus in order to orient to a different stimulus in the environment. Specifically, although anxious individuals were slow to locate a neutral target in the presence of threatening distractors in Experiment 2, they were able to locate a single threat when multiple threats were presented in the current study. Thus, the inability to inhibit threat processing in anxiety may be specific to situations in which neutral and threatening stimuli (rather than multiple threats) compete for attentional resources. In terms of the eye movement system, this would imply that anxiety is associated with an impairment in voluntarily executing an endogenous saccade to a neutral stimulus in the presence of threat. This is consistent with cognitive theories suggesting that an attentional bias to threat in anxiety only occurs when there is competition between a threatening and non-threatening stimulus (Mathews & Mackintosh, 1998).

The results were unexpected because they indicated that target redundancy did not affect the overall speed of orienting towards a target face at the level of the mean or processing capacity to locate a target at the level of the hazard function of the latency distribution. This is inconsistent with the findings of Nelson and Hughes (2007), which showed that the initiation of saccades occurred within a limited capacity processing system in which saccade latencies to a target were slower in the presence of two targets compared with one target. The current findings are seemingly incompatible with the notion that there is response conflict and inhibitory interactions between redundant signals that leads to a slowing of saccadic responses. However, there is a critical difference in the single target stimulus displays used in the two studies that could provide an explanation for the discrepancy in the results. Nelson and Hughes (2007) used single target displays containing one target only (i.e., there were no non-targets). Therefore, there was no response conflict in their single target condition. In contrast, the single target displays used in the current study always contained two items (one target;

one non-target); this was a necessary feature of the design which ensured that participants were actively searching for the emotional face. Although it was necessary to resolve response conflict in the single target and redundant target conditions, it was expected that response conflict would be greater when the two display items shared the same emotional expression. Instead, the results suggest that the response conflict and inhibitory interactions between the two items was equivalent regardless of the expression of each face in the display.

It is important to note that the findings from the single target trials in the current study were similar to the findings from the two-parafoveal condition in the visual search study (Experiment 1). Both types of display contained one target face and one non-target face presented at 4.5 degrees eccentricity to the right and left of central fixation. A similar proportion of the first saccades were accurate in both experiments and there was a tendency for angry faces to be located with greater accuracy compared with happy and neutral faces. However, neither study provided evidence to suggest that the expression of the face affected the speed of orienting towards the target.

A number of limitations should be noted in relation to the current study. Firstly, and most importantly, it is possible that the attentional processes required to locate the target differed in the redundant and single target conditions. Participants needed to make a decision about which target to look at in the redundant target condition; in contrast, it was necessary to discriminate between the target and distractor in the single target condition in order to generate an accurate localisation response. It seems plausible that these different attentional processes were completed within different time frames. Secondly, the accuracy of localisation was very low in the single target condition, suggesting that the similarity between the target and distractor was too high; the implication of this poor performance was that an equivalent proportion of trials (37%) were also removed from the redundant target condition in order to correct for fast guesses. In a related point, it was unclear whether the trials that were removed from the redundant target condition were actually fast guesses because the displays contained only two items and, therefore, responses could not be inaccurate in this condition as a target occupied both display positions. Finally, it is possible that participants were unclear about the task instructions in the redundant target condition; although they were told that it was sufficient to locate one target, they may have felt it necessary to look at both targets. The design of the current study could be significantly improved by systematically manipulating the number of non-targets in the display such that redundant targets were always presented amongst distractors. Under this design, a discrimination process between targets and distractors would be required and inaccurate responses would be possible in the redundant target condition.

In summary, the current study replicated the visual search findings from Experiment 1 to indicate that anxiety was not associated with enhanced localisation of singleton threat; these findings are inconsistent with theories highlighting a selective attentional bias to threat in anxiety (Mogg & Bradley, 1998; Williams et al., 1997). Furthermore, it extended the findings from the remote distractor paradigm (Experiment 2) and the RT redundant signals paradigm (Experiment 3) to suggest that the ability to inhibit threat processing in one location in order to orient attention to threat in a different location is not associated with anxiety. In conjunction with the findings from the remote distractor experiment, this informs current theories of anxiety (e.g., Eysenck et al., 2007; Fox et al., 2001, 2002) by implying that impaired attentional control in anxiety may be specific to situations in which there is competition between threatening and neutral stimuli.

Chapter 7 : General Discussion

7.1 Introduction

Cognitive models of anxiety postulate that the processing and selection of information from the environment differs between anxious and non-anxious individuals. These models have focused on different components of attention including selective attention to threat (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997), impaired attentional control (Eysenck et al., 2007; Fox et al., 2001, 2002) and hypervigilance and enhanced threat detection (Beck et al., 2005; Eysenck, 1992).

Empirical research in the area of anxiety, attention and the threat-related bias is extensive, yet limited by the fact that it has primarily focused on behavioural indices of attention (i.e., RTs; see reviews by Bar-Haim et al., 2007 and Yiend, 2010). While this measure can provide information about the average speed of completing a task in the presence of task-relevant or task-irrelevant threat, it cannot provide information about the timing or nature of the attentional processes that occur prior to the completion of a task. Recent studies have begun to utilise eye movement (e.g., Derakshan et al., 2009; Derakshan & Koster, 2010; Garner et al., 2006; Mogg et al., 2000, 2007) and ERP techniques (Fox et al., 2008; MacNamara & Hajcak, 2010;Mueller et al., 2009) to consider the spatial and temporal characteristics of threat processing in anxiety. However, this is an area that remains relatively under-researched, even though it has the potential to address a number of important research questions related to attentional processes and mechanisms underlying the threat-related bias.

The primary motivation for the empirical studies presented in this thesis was to capture the spatial and temporal characteristics of threat processing and the deployment of attention in anxiety. The experiments utilised eye movement measures and measures of the entire RT distribution; the benefit of these measures is that they can provide a detailed picture of threat processing from the onset of a threatening stimulus until the completion of a task. The current research explored whether anxiety affects the mechanisms and processes that underlie selective attention to threat, impaired attentional control and hypervigilance and threat detection.

Experiment 1 addressed the proposition that anxiety is associated with selective attention to threat (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997); where localisation was identified as a mechanism underlying attentional selection (Posner et al., 1980). It was predicted that a selective attentional bias in anxiety would be reflected in an enhanced ability to locate threat. A localisation version of the visual search paradigm was used to assess whether anxiety was linked to the rapid, accurate and efficient allocation of attentional resources (in this case, eye movements) towards threatening stimuli. However, the results provided no evidence of a relationship between anxiety and the speed or accuracy of locating threat.

Experiment 2 examined the theoretical proposition that anxiety is characterised by impairments in attentional control and, specifically, an inability to inhibit threat processing (Eysenck et al., 2007). Impaired attentional control was defined as an inability to regulate orienting responses (e.g., Derryberry & Reed, 2002) and, given that orienting enables the localisation and selection of high priority stimuli, it was expected that these impairments would affect selective attentional processes. It was predicted that impaired attentional control would lead to an inability to prevent the spotlight of attention moving towards task-irrelevant threat (i.e., attentional capture as indexed by exogenous saccades to a threatening distractor), an inability to shift the spotlight of attention away from task-irrelevant threat (i.e., delayed disengagement as indexed by the slower initiation of endogenous saccades to a target) or an inability to move the spotlight of attention to a task-relevant neutral stimulus in the presence of task-irrelevant threat (i.e., an inability to inhibit threat within a broad attentional beam). The remote distractor paradigm was used to distinguish between these possibilities. The findings from this experiment showed that high levels of trait anxiety were linked to delays in initiating an endogenous saccade to a target when threatening distractors were presented at a variety of locations across the visual field.

Experiment 3 assessed the proposition that individuals with high levels of anxiety are hypervigilant for threat and that this strategy involves maintaining a broad distribution of attention (Eysenck, 1992). It was expected that threat detection would be facilitated if an individual was hypervigilant for threat, if signal strength increased (i.e., from a single threat to multiple threats) and if there was a low criterion for deciding that threat was present in the environment. Experiment 3 considered the cognitive architecture that would allow these factors to enhance threat detection in anxiety. An RT redundant signals paradigm, with concurrent eye movement measures, was employed in Experiment 3 to consider speed and processing capacity to detect multiple and single threats. In this experiment, individuals with high levels of trait anxiety executed fewer eye movements and, thus, were able to efficiently pool evidence for the presence of threat from multiple locations across the visual field.

Experiment 4 used a localisation version of the redundant signals paradigm to revisit each of the research questions raised in the previous studies. It extended the visual search experiment by considering whether anxiety was associated with the ability to locate threat when multiple threats were present in the visual field. It extended the remote distractor experiment by exploring whether individuals with high levels of anxiety were able to inhibit a redundant threat in order to orient attention towards a spatially separate threat target. Finally, it extended the RT redundant signals experiment by considering processing capacity to locate threat in the presence of multiple (vs. single) threatening stimuli in anxiety. This experiment provided no evidence to indicate that there was a relationship between anxiety and the ability to locate threat (as indexed by RTs and processing capacity), regardless of whether a single threat or multiple threats were presented.

The following discussion will initially consider the empirical findings from Experiments 1-4 in the context of the predominant theories of anxiety and attention and, additionally, in the context of models of saccade generation (Findlay & Walker, 1999; Godijn & Theeuwes, 2003). The discussion will then move on to explore the theoretical implications of the empirical findings from Experiments 1-4. Specifically, it will use the findings to identify the attentional processes that are likely to be central to threat processing in anxiety. Finally, the discussion will consider the limitations associated with the current work and the potential directions for future research.

7.2 Attentional Biases to Threat in Anxiety

7.2.1 Selective Attention to Threat in Anxiety

Several conceptual frameworks suggest that anxiety is characterised by selective attention to threat, where attentional resources are allocated to threatening stimuli in preference to non-threatening stimuli at an early stage of processing (Beck & Clark, 1997; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). In terms of the oculomotor system, stimuli that fall within foveal vision receive the highest processing priority due to enhanced visual acuity in this region. Therefore, selective attention to threat should typically be accomplished by overtly orienting visual attention to the threatening stimulus. This would not only enhance threat processing due to greater visual acuity in the fovea, but it would also minimise processing of non-threat stimuli due to the decline in visual acuity in parafoveal and peripheral regions of the visual field.

Based on Findlay and Walker's (1999) model of saccade generation (see Figure 2.1), it was predicted that voluntary search decisions (Level 5) and automated search selection (Level 4) would be biased towards locating threat such that the threshold level of activation required to generate a saccade would be exceeded with greater speed and frequency in anxious (vs. non-anxious) individuals when presented with threats in peripheral or parafoveal locations. This enhanced activation would increase the likelihood of a saccade being triggered and, thus, would ensure that foveal vision was selectively directed to the threatening stimulus in individuals with high levels of anxiety. Contrary to these predictions, the findings from Experiment 1 and Experiment 4 provided no evidence to suggest that anxious and non-anxious individuals differ in their ability to orient foveal vision towards threatening stimuli. In Experiment 1, anxiety was not associated with greater speed, accuracy or efficiency in locating a single threatening stimulus in a parafoveal or peripheral region of the visual field. Experiment 4 extended this finding to indicate that anxiety did not influence the speed of orienting to a single threatening stimulus when multiple threats were present in the visual field. Thus, these studies did not find any evidence to suggest that anxiety affects the mechanisms that should underlie selective attention to threat (i.e., rapid orienting towards and localisation of threat).

The present results were consistent with findings from the spatial cuing paradigm in which there is no evidence of rapid attentional engagement with threat in state or trait anxious individuals (e.g. Fox et al., 2001, 2002). However, the conclusions drawn in this thesis are less consistent with RT findings from the dot probe paradigm. Dot probe studies consistently report that attention is preferentially allocated to threatening (vs. neutral) stimuli in individuals with high levels of anxiety (e.g., Bradley et al., 1998; Mogg et al., 1997, 2004; Mogg & Bradley, 1999, 2002). In contrast with the findings from the current experiments, the typical conclusion drawn from dot probe studies is that there is selective attention and vigilance for threat at an early stage of stimulus processing in anxious individuals. However, an explanation that has the potential to incorporate the current findings was put forward by Koster et al., (2005, 2006). They found evidence to suggest that the RT dot probe findings can be explained by slow and controlled processes such as delayed disengagement from threat rather than early and rapid orienting to threat. While the results of Experiment 1 and Experiment 4 were consistent with the notion that anxiety is unrelated to initial orienting responses, they did not address the possibility that anxiety is characterised by delayed disengagement from threat.

It is more difficult to envisage how delayed disengagement can account for the finding that anxious individuals direct their initial eye movement towards a threatening (vs. neutral) face with greater speed and frequency in the dot probe paradigm (Garner et al., 2006; Mogg et al., 2000, 2007). However, a closer examination of these eye tracking studies suggests that the findings they report could occur as a consequence of later, more controlled attentional processes. Garner et al. (2006), for example, reported that the latency of first fixations that landed on an emotional face (approximately 375 ms) were faster than first fixations that landed on a neutral face (approximately 420 ms) in individuals with high levels of social anxiety. They concluded that there was a rapid initial orienting bias to emotional faces in anxiety. However, the average latency of the first saccade was between 225 ms and 245 ms in the displays containing one target and one distractor in Experiment 1 and Experiment 4 of this thesis. Even allowing approximately 50 ms to execute a saccade to a peripheral target, this indicates that the average latency of the first fixation would be no more than 300 ms in displays containing stimulus pairs. Interestingly, the total time taken before the eyes landed on the target in Experiment 1 (irrespective of the number of saccades executed in the process) was approximately 390 ms in two-peripheral displays, which is more comparable with the latencies reported by Garner et al., (2006).

Therefore, the findings from the current set of experiments question the proposition that previous studies show rapid orienting to threat in anxiety (e.g., Garner et al., 2006). The differences in the latencies of the first eye movements are likely to occur as a consequence of the task demands; participants were explicitly asked to rapidly locate the target with their eyes in Experiment 1 and Experiment 4 of the current research, whereas there were no localisation demands in Garner et al's (2006) study. Therefore, an alternative interpretation of their findings is that anxious individuals initially maintained a wide distribution of attention (i.e. without moving their eyes) and, after processing both stimuli and in the absence of a localisation task, they had a preference to orient to the emotional item. As soon as time demands were implemented (as in Experiment 1 and Experiment 4 of this thesis), this anxiety-based orienting bias disappeared. This interpretation may also apply to Mogg et al's (2007) findings. Here, they report a bias in directing the initial eye movement to threat in anxious individuals but the latencies of the eye movements are not reported. Specifically, in the context of an RT dot-probe paradigm in which emotional-neutral picture pairs were presented, they found that there was a greater proportion of trials in which the initial eye movement was directed towards a threatening face (anger or fear) compared with a neutral face and that this effect was greatest in individuals with high levels of trait anxiety.

Mogg et al. (2000) did find an attentional bias to threat in earlier orienting responses in individuals with GAD. They found that, in comparison with controls, individuals with GAD directed significantly more eye movements towards threatening faces compared with neutral faces; but, in line with Experiment 1 and Experiment 4 from the current work, there were no group differences in the speed of initial eye movements to threat. However, they did find that, unlike the control group, the latency of the initial eye movement towards threat (220 ms) was quicker than the latency of the initial eye movement away from threat (246 ms) in individuals with GAD. However, it is not clear whether these effects were driven by rapid and involuntary attentional capture by the threat stimulus (individuals with GAD were 10 ms faster than controls in directing their eyes towards threat) or difficulties disengaging from threat (individuals with GAD were 23 ms slower than controls in directing their eyes away from threat).

In summary, the results from Experiment 1 and Experiment 4 did not support the theoretical proposition of selective attention and enhanced localisation of threat in anxious individuals. While previous studies suggest that there is a selective attentional bias to threat in anxiety (see review, Bar-Haim et al., 2007), Experiment 1 and Experiment 4 extend this work to highlight that the preferential allocation of attention to threat stimuli is unlikely to occur as a result of rapid or accurate initial orienting to threat. Instead, it is more likely that these previous findings of a selective attentional bias to threat in anxiety arose as a consequence of slower and more controlled processes such as delayed disengagement from threat. However, these conclusions need to be treated with some caution due to the limitations associated with Experiment 1 and Experiment 4; in particular, both studies were limited by the fact that localisation performance was relatively poor across participants irrespective of individual differences in anxiety or the expression of the target face. It is possible that there would be evidence for enhanced localisation and selective attention to threat in anxiety under different experimental conditions (e.g., where target-distractor similarity is reduced). Therefore, future research is required to further explore the relationship between anxiety and threat localisation.

7.2.2 Impaired Attentional Control in Anxiety

Although anxiety was not associated with facilitated orienting to threat, it remained possible that individuals with high levels of anxiety would be unable to regulate orienting responses in the presence of threat. This proposition is consistent with recent conceptual frameworks suggesting that anxiety is characterised by impaired attentional control, where individuals with high levels of anxiety are unable to use goal-directed processes to inhibit threat processing (Eysenck et al., 2007) or disengage from threat (Fox et al., 2001, 2002). In terms of eye movement behaviour, the regulation of orienting responses involves the voluntary suppression or generation of saccades (e.g., Level 5 of Findlay & Walker's, 1999 model; see Figure 2.1). Godijn and Theeuwes (2002, 2003) argued that when endogenous and exogenous stimuli are presented simultaneously, it is necessary to use top-down control (i.e., goal-directed processes) to voluntarily inhibit activation from the exogenous stimulus such that the endogenous stimulus can reach the threshold level of activation required to generate and execute a saccade.

Experiment 2 assessed the relationship between anxiety and the ability to regulate orienting responses when task-relevant (endogenous) neutral stimuli and task-irrelevant (exogenous) threatening stimuli were placed in direct competition for attentional resources. The results from this experiment suggested that individuals with high levels of trait anxiety were able to suppress exogenous saccades to task-irrelevant threat; however, they found it difficult to generate and execute endogenous saccades to task-relevant neutral items in the presence of threatening distractors. Thus, in line with ACT (Eysenck et al., 2007), anxiety was associated with impaired inhibition of threatening distractors and, consequently, a loss of attentional focus on the ongoing task. Furthermore, the findings from Experiment 2 were consistent with findings from RT (Fox et al., 2001, 2002), eye tracking (Derakshan et al., 2009) and ERP (MacNamara & Hajcak, 2010) studies highlighting that anxious individuals are slow to disengage from or inhibit processing of threatening stimuli.

Experiment 2 further questions the proposition that individuals with high levels of anxiety selectively narrow attention onto threat. Firstly, there was no evidence in this task to suggest that individuals with high levels of anxiety involuntarily allocated attentional resources towards task-irrelevant threat (i.e., attentional capture). Secondly, while anxious individuals were slow to orient towards the target in the presence of threat, it was difficult to incorporate this attentional bias within a spotlight metaphor of attention because it occurred for parafoveal and peripheral distractors as well as central distractors. Instead, the results were more consistent with the notion that individuals with high levels of anxiety adopt a wide distribution of attention, where a cost of this strategy is an inability to inhibit processing of threatening stimuli presented in a variety of locations across the visual field (Eysenck, 1992; Eysenck et al., 2007). In terms of orienting responses, this inability to inhibit threat was reflected in difficulties directing a spotlight of attention to non-threat stimuli in the environment (as indexed by delayed endogenous saccades). This indicates that individuals with high levels of anxiety are reluctant to focus attention on a neutral stimulus that is relevant to ongoing task demands when it is known that threats are present in other areas of the environment.

Experiment 4 aimed to extend these findings by assessing the possibility that individuals with high levels of anxiety find it difficult to orient towards and locate a single threat when multiple threats are present in the visual environment. Specifically, an individual with high levels of anxiety may be reluctant to orient towards and focus attention on one threat as this will minimise processing of additional threats that are known to be present in other locations. Contrary to this prediction, anxiety was not associated with impaired threat localisation in the presence of multiple threats (as indexed by overall speed and processing capacity); that is, anxious individuals were able to inhibit processing of redundant threats.

Taken together, the findings from Experiment 2 and Experiment 4 suggest that an inability to inhibit processing of a threatening stimulus only occurs when it competes with a neutral stimulus for attentional resources. That is, anxious individuals find it difficult to focus attentional resources on a neutral stimulus when threat is present in the environment. This is partially consistent with the proposition put forward by Mathews and Mackintosh (1998) that an attentional bias to threat only occurs if there is competition between a threatening and non-threatening stimulus. These conclusions shed further light on existing eye-tracking studies that report a threat-related bias in initial orienting in anxiety (Garner et al., 2006; Mogg et al., 2000, 2007). The current findings suggest that it is unlikely that this bias occurred as a consequence of attentional capture by threat or focusing a narrow spotlight of attention onto threat. Instead, it is more likely that the difference in initial orienting responses to threatening and neutral stimuli was driven by an inability to inhibit threatening stimuli falling within a broad attentional beam. Thus, anxious individuals were slower and less likely to orient to the neutral item due to interference from the threatening item. In line with RT research indicating that anxiety is associated with impaired inhibition of threat (e.g. Stroop findings; see review by Williams et al., 1996) or delayed disengagement from threat (Fox et al., 2001, 2002; Koster et al., 2005, 2006), the current findings suggest that the apparent bias in initial orienting to threat may occur as a result of later, more controlled processes.

7.2.3 Hypervigilance and Threat Detection in Anxiety

From a theoretical perspective, it has been proposed that individuals with high levels of anxiety maintain a broad focus of attention in order to facilitate threat detection (Eysenck, 1992). Experiment 3 assessed the cognitive mechanisms underlying enhanced threat detection in anxiety and, furthermore, it considered whether enhanced threat detection occurred within a broad focus of attention (with few eye movements) or following excessive scanning of the visual environment with numerous eye movements. It was predicted that a broad focus of attention would be the optimal strategy for threat detection when there were multiple threats occurring at a variety of locations across the visual field.

The findings from Experiment 3 suggested that anxiety was associated with a tendency to maintain fixation such that, when there was no requirement to move the eyes, anxious individuals (vs. non-anxious individuals) executed fewer eye movements in the presence and absence of threat. In relation to Findlay and Walker's (1999) model of saccade generation, this experiment supports the proposition that individuals with high levels of anxiety voluntarily promote fixation as a default strategy that allows them to maintain a broad focus of attention such that they can monitor for the presence of threatening or potentially threatening stimuli across the visual field. This strategy is likely to be implemented at Level 4 and Level 5 of Findlay and Walker's (1999) model (see Figure 2.1); specifically, it is possible that a voluntary bias leads to the suppression of saccades (Level 5) such that, in terms of spatial selection (Level 4), the entire visual field is selected for further processing. This finding also links to the theoretical notion of hypervigilance for threat in anxiety (Eysenck, 1991, 1992) and findings from other studies which suggest that anxious individuals maintain a broad focus of attention, even in the absence of threat (Keogh & French, 1999; Shapiro & Lim, 1989; Solso et al., 1968). In line with Freeman et al., (2000), there was no evidence to suggest that individuals with high levels of anxiety excessively scan the visual environment with numerous eye movements to enhance threat detection. It seems unlikely that scanning would be an effective strategy for detecting threat across the visual field because if foveal vision is directed towards one location, then stimulus processing in this area will be enhanced and stimulus processing in other locations will deteriorate. Therefore, threatening stimuli are less likely to be detected from multiple locations if there is excessive scanning.

Experiment 3 showed that the benefits of this broad focus of attention in anxiety were particularly evident when threats occurred in multiple locations across the visual field. Specifically, individuals with high levels of anxiety were able to pool or co-activate multiple threat signals with greater efficiency compared with non-anxious individuals (as indexed by measures of processing capacity). The evolutionary purpose of a co-active threat detection system would be to ensure that less work (or processing capacity) is required to detect threat as the potential severity of the threatening situation increases (i.e. as the number of threats increase from an angry individual to an angry crowd). This finding does not necessarily imply that anxious individuals are unable to co-activate non-threat signals or that co-activation does not occur in non-anxious individuals. Indeed, the overall results from Experiment 3 highlighted that there was an increase in processing capacity for the detection of multiple (vs. single) threat or non-threat signals across participants. However, the results do imply that anxiety is associated with the efficiency of a co-active threat detection system. Thus, the current work extends previous findings of enhanced detection of singleton threat in anxiety (Byrne & Eysenck, 1995; Eastwood et al., 2005; Juth et al., 2005; Matsumoto, 2010) by suggesting that the cognitive mechanism underlying this improved performance is a co-active threat detection system. The findings are consistent with search slope analyses from visual search studies, which suggest that anxiety is associated with greater efficiency in detecting singleton threat (Eastwood et al., 2005; Matsumoto, 2010).

7.2.4 Summary

The current work demonstrated the utility of employing eye movement measures and measures of the RT distribution to explore the effect of anxiety on attention and threat processing. The current data are consistent with the theoretical proposition that anxiety is characterised by hypervigilance for threat and a broad focus of attention (Eysenck, 1991, 1992), where the outcomes of this approach include enhanced threat detection (Eysenck, 1992) in addition to greater distractibility from threat and a loss of attentional focus on the ongoing task (Eysenck et al., 2007). In contrast, the current findings were inconsistent with the theoretical proposition that individuals with high levels of anxiety selectively focus their attention on threatening stimuli (e.g., Beck & Clark, 1997; Mogg & Bradley, 1998). Finally, the current findings highlighted that the relationship between anxiety and the inhibition and detection of threat was specific to trait anxiety; the threat-related bias was not observed in individuals with high levels of social or state anxiety.

7.3 Theoretical Implications

The results from the empirical studies presented in this thesis concur with the notion that a number of attentional processes differ as a function of anxiety such that anxious individuals are biased towards detecting and processing threatening stimuli. A key consideration for the development of theory and research should be to establish the benefits and costs associated with a broad focus of attention in individuals with high levels of anxiety.

7.3.1 The Benefits of Distributed Attention in Anxiety

The results from the current data suggest that anxiety increases the efficiency of a co-active threat detection mechanism such that anxious individuals have a greater ability to integrate threatening information from across the visual field. Therefore, theoretical frameworks of anxiety and attention need to further consider the factors that may enhance the efficiency of the co-active threat detection system in individuals with high levels of anxiety. The current work and existing cognitive models (Eysenck et al., 2007) suggest that individuals with high levels of anxiety adopt a wide distribution of attention as a default strategy, even when it is unlikely that threat is present in the environment. Therefore, although it is likely that a broad focus of attention is an optimal strategy for threat detection, it is unlikely that this alone can account for the increased ability to co-activate a detection response in anxiety. Instead, it is likely that a wide distribution of attention in conjunction with a greater sensitivity to threat enhances threat detection in anxious individuals. This sensitivity to threat may be due to factors specifically related to target detection (Tanner & Swets, 1954) such as a lowered threshold for deciding that a threat is present. Alternatively, it could be due to factors such as increased reactivity or augmented output from the amygdala in response to threatening stimuli (Bishop, 2007; LeDoux, 1998) or a lowered threshold for evaluating a stimulus as threatening (Mathews & Mackintosh, 1998; Mogg & Bradley, 1998).

7.3.2 The Costs of Distributed Attention in Anxiety

The current work implies that theoretical frameworks need to reconsider the extent of impaired attentional control in anxiety. Eysenck et al. (2007) proposed that a cost associated with a wide distribution of attention is a loss of attentional focus on the ongoing task. Similarly, Beck et al., (2005) suggested that a considerable proportion of an anxious individual's cognitive capacity would be dedicated to scanning the environment for threat and, therefore, it would be difficult to assign attentional resources to ongoing tasks. There are a number of reasons to question the scope of these propositions. In the current data there was no evidence to indicate that individuals with high levels of anxiety excessively scan the environment for threat; instead, the findings suggested that anxiety was associated with fewer eye movements and a broad focus of attention which enabled the processing and detection of threat in parafoveal and peripheral regions of the visual field.

Furthermore, while Eysenck et al., (2007) suggested that impairments in attentional control should occur in the presence of any distractor, albeit to a greater extent for threatening stimuli, these impairments were specific to task-irrelevant threat in the current work. Interestingly, the results also suggested that the impairment in inhibiting processing of threat is specific to situations in which there is competition between a non-threatening and threatening stimulus (see also Mathews & Mackintosh, 1998). In other words, anxious individuals are able to inhibit processing of one threat in order to orient towards another threat, but they are unable to inhibit processing of threat in order to orient towards a neutral stimulus. Thus, the results highlighted that individuals with high levels of anxiety experience difficulties assigning attentional resources to an ongoing task but only in the presence of threat.

In contrast with the notion of impaired attentional control in anxiety, it is possible that the ability to maintain a wide distribution of attention actually requires good attentional control, but only when detecting threat. Belopolsky et al., (2007), for example, suggested that the size of the attentional window may be under top-down control. Future studies that assess the ability to flexibly adjust the attentional window in order to optimally detect threat in anxiety will provide further insight into this proposition.

7.4 Limitations

It is important that future research establishes whether there are quantitative differences between sub-clinical and clinical populations for the effects reported in this thesis (though note that Bar-Haim et al., 2007 reported similar effect sizes for the threat bias in clinical and sub-clinical samples). The current work considered the relationship between anxiety and attention in a sample of participants from a typical population. There are practical and theoretical advantages in adopting this approach. From a practical perspective, it is easier to obtain data from this population and, therefore, this approach avoids the problems associated with making inferences based on small clinical samples. From a theoretical perspective, the differences between clinical and sub-clinical anxiety are typically regarded as variations on a dimensional construct rather than representing qualitatively distinct categories (Beck & Clark, 1997; Hadwin & Field, 2010; Yiend, 2010).

The current work relied on self-report measures of anxiety and attentional control. This is an approach that is typically adopted in anxiety research and there is considerable evidence to suggest that the anxiety measures have good psychometric properties. In contrast, the ACS is a more recent measure that is used less frequently in comparison with the anxiety measures. The reliability and validity of this measure is not as clear; indeed, the current work reported lower, albeit acceptable, internal consistency for this measure compared with the anxiety measures. Therefore, it is unclear whether self-reported attentional control was highly correlated with actual attentional control capacities; a behavioural measure of attentional control would serve to validate the findings (see Reinholdt-Dunne et al., 2009 for a study in which there was no evidence of an association between self-reported and behavioural measures of attentional control).

Theories and research have suggested that the threat bias is particularly apparent in high trait anxious individuals who are also high in state anxiety (Eysenck, 1992; Eysenck et al., 2007; Mogg & Bradley, 1998) or low in attentional control (Derryberry & Reed, 2002; Lonigan et al., 2004). Although there was no evidence to support either of these propositions in the current work, the state anxiety scores were relatively low with a maximum of 15% of any sample being identified as 'high' state anxious. In contrast, research reporting an interaction between state and trait anxiety has typically used mood manipulations to experimentally enhance state anxiety levels (Keogh & French, 1999; Markowitz, 1969). Therefore, future work is required to consider the effects reported in this thesis when state anxiety is manipulated. A similar criticism can be made in relation to the interaction between trait anxiety and attentional control; there were significant negative correlations between self-report trait anxiety and attentional control and, therefore, it may be that an insufficient proportion of the sample reported high trait anxiety and high attentional control. In order to fully assess this interaction, future research should screen participants prior to testing to ensure that samples consist of similar numbers of high trait anxious individuals reporting high and low attentional control.

Finally, it could also be argued that the effects were attributable to low level features of the angry faces rather than the emotional content per se. This is deemed unlikely because at least 8 models were used as photographic stimuli for each emotion in every study. Therefore, a low level feature account would require that the feature was present in the whole set of angry faces and absent in the whole set of happy and neutral faces and, furthermore, that anxiety was related to processing this feature.

7.5 Directions for Future Research

This thesis highlights that the distribution of attention and its associated benefits for threat detection are potentially important factors in understanding the cognitive basis of anxiety. There is currently a paucity of literature in this area, though it appears to be a particularly fruitful direction for future research. In the short term, a number of questions need to be addressed in relation to the flexibility of the attentional beam and the parameters and neural mechanisms underlying a co-active threat detection system. In the longer term, it would be of interest to consider whether the flexibility of the attentional beam and enhanced functioning of a co-active threat detection system are factors that cause or maintain elevated anxiety. If this is the case, then it will have implications for extending the Attention Training Techniques (ATTs) that are currently implemented in the treatment of individuals with high levels of anxiety (Bar-Haim, 2010; Cowart & Ollendick, 2010; MacLeod, 2010).

7.5.1 Co-activation and the Breadth of Attention

It is important that future research determines the parameters in which a co-active threat detection system can operate in order to understand the full extent of the relationship between anxiety, threat detection and the distribution of attention. It is possible that a wide distribution of attention is only an optimal strategy for threat detection under conditions that allow co-activation. When it is not possible to co-active threat signals, a more effective strategy may be to scan the environment with rapid eye movements. Thus, anxious individuals may adopt different strategies (i.e. a wide distribution of attention vs. excessive scanning) to enhance threat detection depending on the demands of the situation. The sections below provide examples of experimental manipulations that could be used to explore the relationship between anxiety and the parameters of the co-active threat detection system.

Perceptual load. Neuroimaging studies suggest that the relationship between anxiety and the amygdala response to threatening distractors is only apparent under conditions of low perceptual load (Bishop et al., 2007; Bishop, 2009), where the typical explanation for this finding is that there are no attentional resources available to process the threatening distractors under conditions of high perceptual load. Although the threatening stimuli serve as targets in the redundant signals paradigm, it would still be of interest to consider whether the enhanced ability to co-activate threat signals occurs under conditions of high perceptual load in individuals with high levels of anxiety. One means of increasing perceptual load is to increase set size (Lavie, Ro, & Russell, 2003). In the context of the redundant signals paradigm, this would be achieved by increasing the number of non-threatening distractors in the display. It seems possible that the magnitude of the relationship between anxiety and processing capacity may increase under conditions of high perceptual load because anxious individuals will invest greater effort in threat detection compared with non-anxious individuals and, therefore, they will have less attentional capacity available to process non-threatening distractors (Lavie, 2005).

The number of threatening stimuli. It is of interest to establish how many threatening stimuli can be used to co-activate a detection response. It is possible that the magnitude of the relationship between processing capacity and anxiety will increase with an increasing number of threats because anxious individuals will be able to co-activate all threatening signals that fall within their broad attentional beam. However, it is likely that there will be an asymptotic effect on the relationship between anxiety and processing capacity, where the detection responses of anxious individuals cannot be improved any further after reaching a threshold number of threats in the environment. It is possible that individuals with high levels of anxiety switch from a broad to a narrow focus of attention at the onset of this asymptotic effect; if there are a large number of threats, it may be that anxious individuals scan the visual environment with excessive and rapid eye movements in order to detect and process every threatening stimulus.

The flexibility of the attentional beam. It has previously been argued that neither the spotlight nor zoom lens metaphors of attention are sufficient explanations of the deployment of attention. Both accounts suggest that the attentional beam falls over one contiguous location. In contrast, there is evidence to suggest that two targets can be identified when they are presented simultaneously and separated by intervening distractors (Bichot, Cave, & Pashler, 1999). Therefore, attention can be divided between non-contiguous target locations without simultaneously selecting intervening distractor locations. These findings suggest that attention can be deployed flexibly depending on the task demands. Therefore, it is important to establish whether individuals with high levels of anxiety flexibly deploy attention to optimise threat detection across a variety of situations. For example, it is of interest to consider whether the relationship between anxiety and processing capacity for threat detection also occurs when the target signals are separated by an intervening non-threat distractor. This would provide an insight into the extent to which the distribution of attention is under top-down control in anxious individuals.

7.5.2 Neural Co-activation

An important line of enquiry for future research is to consider the neural basis of co-active processing during threat detection in anxious and non-anxious individuals. Previous research has concurrently used behavioural and ERP measures to consider the redundancy gain and neural co-activation (Miniussi, Girelli, & Marzi, 1998). Miniussi et al., (1998) presented either one unilateral target or two bilateral targets in peripheral locations. They reported a redundancy gain in the behavioural RT data that was consistent with a co-activation model (i.e., there was a violation of the race model inequality). They also found evidence of neural co-activation in extrastriate visual areas, where the latency of the P1 and N1 components were shorter when two stimuli were presented bilaterally compared with when one stimulus was presented unilaterally.

In light of these findings, it would be of interest to consider whether there is evidence of neural co-activation when detecting threat in the presence of multiple (vs. single) targets and, furthermore, whether the magnitude of this effect is greater in individuals with high levels of anxiety. For example, it is possible that anxiety would modulate neural co-activation as indexed by the latency and/or amplitude of the P1 component. The allocation of covert visuospatial attention to a stimulus is reflected in an enhanced occipital P1 response at 80-110 ms post stimulus onset (Bar-Haim, Lamy, & Glickman, 2005). Previous research indicates that the P1 amplitude is greater in response to threatening (vs. positive) stimuli in individuals with high levels of anxiety (Li, Zinbarg, Boehm, & Paller, 2008; Mueller et al., 2009) and it is argued that this effect may reflect hypervigilance for threat. Therefore, if anxiety is associated with hypervigilance, a wide distribution of attention and a co-active threat detection system, then there should be evidence of enhanced neural co-activation in the amplitude or latency of the P1 component in anxious individuals when presented with multiple (vs. single) threats.

7.5.3 Clinical Implications

Given the possible role of attentional biases in the development and maintenance of elevated anxiety and anxiety disorders, it has been suggested that clinicians should apply therapeutic interventions that serve to reduce attentional biases to threat (Mobini & Grant, 2007). Attention training techniques (ATTs) have also been used to modify attentional biases to threatening stimuli (Bar-Haim, 2010; Cowart & Ollendick, 2010; MacLeod, 2010). ATTs aim to reduce anxiety by using experimental tasks (e.g., the dot probe paradigm) that train individuals with high levels of anxiety to shift their attention away from negative or threatening stimuli and towards neutral stimuli. Research indicates that extended exposure to these techniques successfully modifies attentional biases to threat and, more importantly, reduces trait anxiety, state anxiety and clinical symptoms in individuals with social anxiety disorder and GAD (Bar-Haim, 2010; Cowart & Ollendick, 2010; MacLeod, 2010).

The current findings fit well with the rationale underlying ATTs, which suggests that individuals with high levels of anxiety require training to direct attentional resources towards neutral stimuli when threat is present in the environment. However, if it is the case that a wide distribution of attention and a co-active threat detection system cause, maintain or exacerbate anxiety, then this has important implications for extending the existing ATTs. Specifically, the current findings raise the possibility that cognitive modification procedures should also aim to reduce the breadth of attention prior to threat detection in individuals with high levels of anxiety.

7.6 Conclusion

The results presented in this thesis extend existing theories and research by highlighting that sensitivity to threat in anxiety can be understood most effectively within a conceptual framework that emphasises the costs, benefits and purpose of a wide distribution of attention in anxious individuals. Most importantly, this framework would propose that individuals with high levels of anxiety frequently adopt a broad focus of attention, which ensures that they are hypervigilant for threat. The benefit of this strategy is that it allows enhanced threat detection, especially in the presence of multiple threats, due to a greater ability to integrate threat signals from an extensive region of the visual field. However, the strategy also comes at a cost; specifically, it increases the likelihood of distraction by task-irrelevant threat due to a failure to inhibit threat processing within the broad attentional beam. Future research is required to understand the parameters of these attentional processes and to consider how the findings can be used in a clinical setting to modify the breadth and direction of attention in individuals with high levels of anxiety.

Appendix A: Examples of Participant Consent and Debriefing Forms

A.1 Participant Information Sheet

Study Title: Eye movements and visual search for emotional faces
Researchers: Helen Richards, Dr. Julie Hadwin, Dr. Valerie Benson & Professor Nick Donnelly.
Ethics number: 851

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
I am Helen Richards, a PhD student at the University of Southampton. This research will assess individual differences in the speed and accuracy of searching for and detecting emotional faces. The research will also consider whether emotions and concentration affect the way in which attention is allocated to emotional stimuli

Why have I been chosen?
You will have been asked to participate in this study based on the responses you provided in the online questionnaire about your emotions and perceptions in social situations. The purpose of the online questionnaire was to select an equal number of participants with above average and below average scores on this measure.

What will happen to me if I take part?
In the initial phase of the experiment, you will be asked to spend a couple of minutes completing a short questionnaire about how you are feeling at that particular moment in time. In the second phase of the experiment, you will be asked to participate in a computer based task for 45-60 minutes. This task will involve searching for and deciding upon the presence or absence of an emotional face, presented amongst neutral faces. Your eye movements will be monitored by a camera as you carry out this task. The final phase of the experiment will involve completing four short questionnaires about your emotions and your ability to concentrate. These questionnaires will take approximately 10-15 minutes to complete.

Are there any benefits in my taking part?

Your contribution to this study will add to current knowledge in the field of emotion and attention. You will also be paid £7.50 or allocated 5 credits for your participation.

Are there any risks involved?

There are very few risks involved in this study. The eye tracking equipment is entirely non-invasive and should not cause any discomfort. You will be provided with breaks throughout the experiment (and you can ask for any additional breaks that you feel you need at any time). Your questionnaire responses will be confidential and will only be viewed by the researchers involved in this project. If the study raises any questions or concerns, please do not hesitate to contact the experimenter or the helpline number provided on the debriefing statement.

Will my participation be confidential?

This study complies with the Data Protection Act/University policy. Your confidentiality will be maintained at all times. Your responses will be stored on a password protected computer and/or stored in a locked filing cabinet.

What happens if I change my mind?

You have the right to withdraw consent to participate at any time (before, during or after the experiment) without any penalty or consequence to your grades or your treatment as a student.

What happens if something goes wrong?

In the unlikely case of concern or complaint, you should contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ. Tel: 023 8059 3995

Where can I get more information?

If you have any questions please ask them now, or contact Helen Richards at hjr105@soton.ac.uk

A.2 Participant Consent Form

Eye movements in visual search for emotional faces

Consent Form

I am Helen Richards, a postgraduate student completing a PhD at the University of Southampton. I am requesting your participation in a study which will assess individual differences in the speed and accuracy of searching for and detecting emotional faces. This study will involve taking part in a simple computer based task. You will be asked to indicate whether an emotional face is present or absent among displays containing neutral faces. Your eye movements will be recorded by a camera as you do this. The study will also involve completing four short questionnaires, asking you to rate your emotions (e.g. 'I feel upset', 'I feel pleasant') and asking you to rate your ability to concentrate on your work (e.g. 'It is hard for me to concentrate on a difficult task when there are noises around'). The study will last approximately 1 hour and 15 minutes in total.

Personal information will not be released to or viewed by anyone other than researchers involved in this project. Results of this study will not include your name or any other identifying characteristics. Your participation is voluntary and you may withdraw your participation at any time. **If you choose not to participate there will be no penalty or consequences to your grade or to your treatment as a student in the psychology department.** If you have any questions please ask them now, or contact Helen Richards at hjr105@soton.ac.uk.

Name: ……………….……….. Signature: ………………………. Date: ……………

Statement of Consent

I __________________________ have read the above informed consent form.

I understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. I understand that data collected as part of this research project will be treated confidentially, and that published results of this research project will maintain my confidentially. In signing this consent letter, I am not waiving my legal claims, rights, or remedies. A copy of this consent letter will be offered to me.

I give consent to participate in the above study. **(Circle Yes or No)** Yes No

Signature Date

Name

I understand that if I have questions about my rights as a participant in this research, or if I feel that I have been placed at risk, I can contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: (023) 8059 3995.

A.3 Participant Debriefing Form

Eye movements in visual search for emotional faces

Debriefing Statement

The aim of this research was to investigate individual differences in the speed and accuracy of searching for angry and happy faces. There is evidence to suggest that there is an automatic attentional bias towards threatening stimuli in anxious individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & Ijzendoorn, 2007). In the current study, it was expected that the speed of moving the eyes towards an angry target face would be greater in individuals reporting higher levels of anxiety (vs. individuals reporting lower levels of anxiety). Similarly, it was expected that the time taken to manually indicate the presence or absence of an angry target face would be reduced in anxious individuals. Furthermore, it was expected that very early stages of search performance would be enhanced on trials containing two angry target faces compared with one angry target face in individuals reporting higher levels of anxiety. This finding would indicate that, when there is more than one source of threat in the environment, anxious individuals are able to simultaneously process these threatening items. The study also aims to consider the moderating effects of attentional control. Specifically, it is expected that this bias towards angry faces in anxious individuals will be especially evident in participants who also report low levels of attentional control (i.e. difficulties in shifting and focusing their attention).

Once again results of this study will not include your name or any other identifying characteristics. The experiment did not use deception. You may have a copy of this summary if you wish and a summary of the research findings on completion of the project.

If you have any further questions please contact Helen Richards at hjr105@soton.ac.uk.

Alternatively, if participation in this study has raised any issues that you wish to discuss in confidence, the University provides a confidential helpline. Phone: 023 8059 3719.

Thank you very much for your participation in this research.

Signature: ………………………………. Date: ………………………..

Name: ……………………………………

If you have any questions about your rights as a participant in this research, or if you feel that you have been placed a risk, you may contact the Chair of the Ethics Committee, Department of Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: (023) 8059 3995

Appendix B: Rating Responses for the NimStim Models

B.1 Aims

To ensure that the facial expressions used in the empirical studies throughout this thesis were perceived as expressing the intended emotion[4].

B.2 Method

B.2.1 Participants

24 undergraduate students (*Mean age* = 19.21 years, *SD* = 0.87, *range* = 18-21; 3 males) from the University of Southampton.

B.2.2 Stimuli

20 models were selected from the NimStim Face Set (Tottenham et al, 2009) based on validity ratings provided with the stimulus set. There were 7 facial expressions associated with each model: neutral, sad, surprised, happy, disgusted, fearful and angry. There were two versions of each expression; open-mouth and closed-mouth. Only the angry, happy and neutral faces will be considered here.

B.2.3 Procedure

Participants viewed each face separately and rated the extent to which it expressed neutrality, sadness, surprise, happiness, disgust, fear and anger. Ratings were made on a 9-button response box ranging from 1 ('not at all') to 9 ('extremely'). Only the angry, happy and neutral rating responses will be considered here.

B.3 Results

Paired sample t-tests indicated that the open mouth versions of the angry faces were rated significantly higher for anger compared with the closed mouth versions of the angry faces, $t(23) = 6.33$, $p < .001$, $d = 0.60$. The open mouth versions of the happy faces were rated significantly higher for happiness compared with the closed mouth versions of the happy faces, $t(23) = 5.02$, $p < .001$, $d = 0.73$. The closed mouth version

[4] This pilot study was conducted in collaboration with Abigail Lucas and was submitted as an experimental research project for the MSc in Research Methods in Psychology at the University of Southampton (this MSc was awarded to Helen Richards in 2007).

of the neutral faces was rated significantly higher for neutrality compared with the open mouth version of this expression, $t(23) = 3.00$, $p < .05$, $d = 0.30$. Therefore, only the open mouth versions of angry and happy faces and the closed mouth versions of neutral faces were used in the empirical studies presented throughout this thesis.

The 16 NimStim models with the highest ratings for the intended emotion (e.g. high anger ratings for angry faces) and the lowest ratings for unintended emotions (e.g. happy ratings for angry faces) were selected. These were models 1, 5, 9, 10, 12, 13, 14, 18, 22, 23, 26, 34, 36, 37, 38, 40 from the NimStim database. The mean angry, happy and neutral ratings for the angry, happy and neutral faces from this subset of 16 models are provided in Table B1.

Table B1
Mean (+*SD*) rating responses for the angry, happy and neutral faces.

	Anger rating		Happy rating		Neutral rating	
	M	*SD*	*M*	*SD*	*M*	*SD*
Angry faces (o)*	7.42	0.51	1.67	0.24	1.97	0.21
Happy faces (o)*	1.39	0.11	7.73	0.40	2.93	0.40
Neutral faces (c)*	3.36	0.54	2.98	0.52	7.05	0.42

*o = open mouth version of the expression; c = closed mouth version of the expression

B.4 Conclusion

The intended emotion of the facial expressions was perceived at a high level in this subset of 16 NimStim models.

Appendix C: Recognition of Facial Expression in Parafoveal and Peripheral Vision.

C.1 Aim

To ensure that the intended emotion of the faces used in the empirical studies could be recognised in parafoveal and peripheral locations in the absence of overt eye movements to the face.

C.2 Method

C.2.1 Participants

Four postgraduate students (*Mean age* = 27.75 years, *SD* = 3.34, *range* = 24-33; 1 male) from the University of Southampton.

C.2.2 Stimuli

The stimuli consisted of the angry, happy and neutral faces from the 16 NimStim models that were used throughout this thesis. Each stimulus display consisted of a face presented in one of four possible locations: a) at a parafoveal location to the right of fixation; b) at a parafoveal location to the left of fixation; c) at a peripheral location to the right of fixation or; d) at a peripheral location to the left of fixation. Parafoveal and peripheral faces were presented at 4 degrees eccentricity and 8 degrees eccentricity, respectively.

C.2.3 Procedure

Participants completed 96 trials. There were an equal proportion of trials associated with each expression and the target appeared in every possible location with an equal frequency. For each trial, a central fixation cross was presented for 1000 ms. This was followed by the stimulus display, which remained on the screen until the participant made a button-press response. A trial ended with a blank screen, which was presented for 1000 ms.

Participants were instructed to keep their eyes focused on the centre of the screen at all times and not to look at the faces. They were asked to make a button-press response to indicate whether the face presented in each display was angry, happy or neutral. The buttons assigned to each emotion were counterbalanced across participants.

C.3 Results

Trials were excluded from the analysis if the participant moved their eyes (*M* = 10.75 trials, *SD* = 3.70, *range* = 6-16 trials). A repeated measures ANOVA was conducted with eccentricity (parafoveal and peripheral) and expression (angry, happy and neutral) as within-subject variables. The dependent variable was the percentage of correct categorisations of the facial expressions. There was no significant main effect of eccentricity or expression and there was also no interaction between these variables. Although non-significant, Table C1 shows that the percentage of correct categorisations was higher for parafoveal compared with peripheral faces. Table C2 presents the percentage of correct categorisations associated with each expression.

Table C1

Descriptive statistics for the percentage of correct categorisations as a function of eccentricity

	M	*SD*	*Minimum*	*Maximum*
Parafoveal faces	97.76	1.72	92.31	100
Peripheral faces	94.84	3.26	81.25	100

Table C2

Descriptive statistics for the percentage of correct categorisations as a function of expression.

	M	*SD*	*Minimum*	*Maximum*
Angry faces	97.55	1.66	92.86	100
Happy faces	93.29	4.14	81.25	100
Neutral faces	98.07	2.24	91.67	100

C.4 Conclusions

Emotional (angry and happy) and non-emotional (neutral) faces can be recognised with a high level of accuracy (> 90%) when they are presented in parafoveal or peripheral regions of the visual field.

Appendix D: Questionnaire Measures

D.1 State Version of the State-Trait Anxiety Inventory for Adults (Spielberger, 1983)

Instructions: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to indicate how you feel *right now*, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on one statement but give the answer which seems to describe your present feelings best.

1 = Not at all 2 = Somewhat 3 = Moderately so 4 = Very much so

1. I feel calm
2. I feel secure
3. I am tense
4. I feel strained
5. I feel at ease
6. I feel upset
7. I am presently worrying over possible misfortunes
8. I feel satisfied
9. I feel frightened
10. I feel comfortable
11. I feel self-confident
12. I feel nervous
13. I am jittery
14. I feel indecisive
15. I am relaxed
16. I feel content
17. I am worried
18. I feel confused
19. I feel steady
20. I feel pleasant

D.2 Trait Version of the State-Trait Anxiety Inventory for Adults (Spielberger, 1983)

Instructions: A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to indicate how you *generally* feel.

1 = Almost never 2 = Sometimes 3 = Often 4 = Almost always

1. I feel pleasant
2. I feel nervous and restless
3. I feel satisfied with myself
4. I wish I could be as happy as others seem to be
5. I feel like a failure
6. I feel rested
7. I am "calm, cool and collected"
8. I feel that difficulties are piling up so that I cannot overcome them
9. I worry too much over something that really doesn't matter
10. I am happy
11. I have disturbing thoughts
12. I lack self-confidence
13. I feel secure
14. I make decisions easily
15. I feel inadequate
16. I am content
17. Some unimportant thought runs through my mind and bothers me
18. I take disappointments so keenly that I can't put them out of my mind
19. I am a steady person
20. I get in a state of tension or turmoil as I think over my recent concerns and interests

D.3 Social Interaction Anxiety Scale (Mattick & Clark, 1998)

Instructions: Indicate the degree to which you feel each statement is characteristic or true of you.

0 = Not at all 1 = Slightly 2 = Moderately 3 = Very 4 = Extremely

1. I get nervous if I have to speak with someone in authority (teacher, boss, etc).
2. I have difficulty making eye-contact with others.
3. I become tense if I have to talk about myself or my feelings.
4. I find difficulty mixing comfortably with the people I work with.
5. I tense-up if I meet an acquaintance in the street.
6. When mixing socially I am uncomfortable.
7. I feel tense if I am alone with just one other person.
8. I am at ease meeting people at parties, etc.
9. I have difficulty talking with other people.
10. I find it easy to think of things to talk about.
11. I worry about expressing myself in case I appear awkward.
12. I find it difficult to disagree with another's point of view.
13. I have difficulty talking to attractive persons of the opposite sex.
14. I find myself worrying that I won't know what to say in social situations.
15. I am nervous mixing with people I don't know well.
16. I feel I'll say something embarrassing when talking.
17. When mixing in a group I find myself worrying I will be ignored.
18. I am tense mixing in a group.
19. I am unsure whether to greet someone I know only slightly.

D.4 Fear of Negative Evaluation Scale (Watson & Friend, 1969)

Instructions: Please show your reactions to the following statements by circling 'True' or 'False'. Answer the questions quickly without thinking too much about them.

1. I rarely worry about seeming foolish to others.
2. I worry about what people will think of me even when I know it doesn't make any difference.
3. I become tense and jittery if I know someone is sizing me up.
4. I am unconcerned even if I know people are forming an unfavourable impression of me.
5. I feel very upset when I commit some social error.
6. The opinions that important people have of me cause me little concern.
7. I am often afraid that I may look ridiculous or make a fool of myself.
8. I react very little when other people disapprove of me.
9. I am frequently afraid of other people noticing my shortcomings.
10. The disapproval of others would have little effect on me.
11. If someone is evaluating me I tend to expect the worst.
12. I rarely worry about what kind of impression I am making on someone.
13. I am afraid that others will not approve of me.
14. I am afraid that people will find fault with me.
15. Other people's opinions of me do not bother me.
16. I am not necessarily upset if I do not please someone.
17. When I am talking to someone, I worry about what they may be thinking of me.
18. I feel that you can't help making social errors sometimes so why worry about it.
19. I am usually worried about what kind of impression I make.
20. I worry a lot about what my superiors think of me.
21. If I know someone is judging me, it has little effect on me.
22. I worry that others will think I am not worthwhile.
23. I worry very little about what others may think of me.
24. Sometimes I think I am too concerned with what other people think of me.
25. I often worry I will say or do the wrong things.
26. I am often indifferent to the opinions others have of me.
27. I am usually confident that others will have a favourable impression of me.
28. I often worry that people who are important to me won't think very much of me.
29. I brood about the opinions my friends have of me.

30. I become tense and jittery if I know I am being judged by my superiors.

D.5 Attentional Control Scale (Derryberry & Reed, 2002)

Instructions: These questions are about how well you feel you concentrate on your work. Please answer each item, indicating how often it is true for you on the scale beside each question.

1 = Almost never 2 = Sometimes 3 = Often 4 = Always

1. It's very hard for me to concentrate on a difficult task when there are noises around.
2. When I need to concentrate and solve a problem, I have trouble focusing my attention.
3. When I am working hard on something, I still get distracted by events around me.
4. My concentration is good even if there is music in the room around me.
5. When concentrating, I can focus my attention so that I become unaware of what's going on in the room around me.
6. When I am reading or studying, I am easily distracted if there are people talking in the same room.
7. When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.
8. I have a hard time concentrating when I am excited about something.
9. When concentrating I ignore feelings of hunger or thirst.
10. I can quickly switch from one task to another
11. It takes me a while to get really involved in a new task.
12. It is difficult to coordinate my attention between the listening and writing required when taking notes during lessons.
13. I can become interested in a new topic very quickly when I need to.
14. It is easy for me to read or write while I am also talking on the phone.
15. I have trouble carrying out two conversations at once.
16. I have a hard time coming up with new ideas quickly.
17. After being interrupted or distracted, I can easily switch my attention back to what I was doing before.
18. When a distracting thought comes to mind, it is easy for me to shift my attention away from it.
19. It is easy for me to alternate between two different tasks.
20. It is hard for me to break from one way of thinking about something and look at it from another point of view.

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