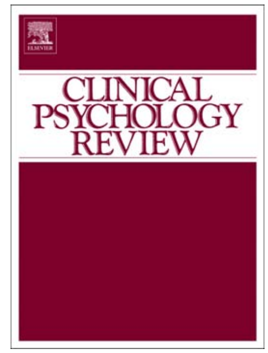

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Exploring the Function of Selective Attention and Hypervigilance for Threat in Anxiety

Running Head: Anxiety, Selective Attention and Hypervigilance

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Abstract

Theoretical frameworks of anxiety propose that attentional biases to threat-related stimuli cause or maintain anxious states. The current paper draws on theoretical frameworks and key empirical studies to outline the distinctive attentional processes highlighted as being important in understanding anxiety. We develop a conceptual framework to make a distinction between two attentional biases: selective attention to threat and hypervigilance for threat. We suggest that these biases each have a different purpose and can account for the typical patterns of facilitated and impaired attention evident in anxious individuals. The framework is novel in its specification of the eye movement behavior associated with these attentional biases. We highlight that selective attention involves narrowing overt attention onto threat to ensure that these stimuli receive processing priority, leading to rapid engagement with task-relevant threat and delayed disengagement from task-irrelevant threat. We show that hypervigilance operates in the presence and absence of threat and involves monitoring for potential dangers via attentional broadening or excessive scanning of the environment with numerous eye movements, leading to improved threat detection and increased distraction from task-irrelevant threat. We conclude that future research could usefully employ eye movement measures to more clearly understand the diverse roles of attention in anxiety.

Keywords: anxiety, eye movements, threat, selective attention, hypervigilance

Exploring the Function of Selective Attention and Hypervigilance for Threat in Anxiety

In a recent meta-analysis, Armstrong and Olatunji (2012) reviewed free viewing and visual search eye movement paradigms in attention and anxiety. They argued that the findings of this research are consistent with theoretical models that highlight increased vigilance for threatening stimuli in individuals with elevated or clinical levels of anxiety. They further suggested that this attentional system is capacity limited and is most evident in studies that include paradigms with a limited range of eccentricity and with a low perceptual load. In addition, they highlighted that support for the theoretical proposition that increased anxiety is linked to difficulties disengaging from threat is only evident in certain viewing contexts.

The current paper extends the basic arguments made in this meta-analysis to explore how eye movement paradigms can be used to test theoretical propositions linked to hypervigilance in anxiety, in addition to those that focus on selective attention. It highlights the distinct role of anxiety-related hypervigilance for threat by drawing on theoretical models of attention and anxiety and empirical findings that have used eye movement, neuroimaging and behavioral measures. We present a novel theoretical framework supported by findings from key empirical papers which demonstrates that selective attention and hypervigilance for threat are separable processes in anxiety. Moreover, we show how these different processes can be distinguished by their evolutionary function, their underlying mechanisms, the environmental or experimental conditions in which they occur, and the patterns of facilitated and impaired attention they generate, as shown in eye movement behaviors.

Selective Attention to Threat

The most consistent prediction to emerge from theoretical accounts of anxiety and attention is that there is a selective attentional bias to threat in anxiety, where individuals with high (vs. low) levels of anxiety selectively narrow attention onto threat stimuli in preference to neutral stimuli. Theoretical accounts typically consider the possibility that this selective attentional bias consists of vigilance for threat (also referred to as rapid orienting and engagement of attention with threat) or attention maintenance on threat (also referred to as delayed disengagement from threat).

The Orienting Network

Armstrong and Olatunji (2012) proposed that the orienting network outlined by Posner and colleagues (e.g., Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Posner, 2012; Posner & Rothbart, 2007) provides an effective framework with which to understand selective attentional processes. In humans, the cognitive system has a limited capacity to process all available sensory information and it needs to be able to select relevant stimuli for further processing (Hutton, 2008), especially if the stimuli are relevant to survival (Dolan & Vuilleumier, 2003). The orienting network is involved in selectively allocating attention to relevant objects/locations in order to enhance perceptual processing in these regions of the visual field (e.g., Fan et al., 2005; Posner, 2012; Posner & Petersen, 1990; Posner & Rothbart, 2007; Rueda, Posner, & Rothbart, 2005). Orienting includes aligning attention with sensory stimuli by disengaging attention from the current location, shifting attention to and engaging it at a new location (Posner & Petersen, 1990). The purpose of orienting visual attention to a new stimulus or location is to change the distribution of processing resources across the visual field; that is, processing priority is reassigned as demonstrated by increased neural activity and processing speed in response to stimuli within the newly attended region (see Kastner & Ungerleider, 2000; Raz & Buhle, 2006). Furthermore, selectively orienting attention to a relevant stimulus reduces the neural interference and competition for processing resources from task-irrelevant stimuli that fall outside the attended region (see Kastner & Ungerleider, 2000; Raz & Buhle, 2006). The brain regions underlying the orienting process have been described extensively and consist of fronto-parietal networks including the superior parietal lobe, temporoparietal junction, superior colliculus, and frontal eye fields (Posner, 2012; Posner & Peterson, 1990; Raz & Buhle, 2006).

The process of orienting can occur overtly or covertly (Moore, Armstrong & Fallah, 2003; Posner, 2012). Overt orienting involves moving attention to a location by moving the eyes such that there is an alignment between the direction of gaze and the direction of attention (Moore, et al., 2003; Posner, 2012). Due to the physiological constraints of the oculomotor system, the selection of visual information in a cognitive visual task is typically accomplished by overtly orienting the eyes to appropriate locations in the visual field (Liversedge & Findlay, 2000). 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). Eye movements (saccades) are required to align the high acuity area of the retina (i.e., the fovea) with potential objects of interest to allow a detailed inspection during fixation (Liversedge & Findlay, 2000). Peripheral vision guides eye movements by providing information about the nature and location of potential objects of interest (Findlay & Gilchrist, 2003; Hutton, 2008; Liversedge & Findlay, 2000).

Covert orienting involves moving attention to a location without moving the eyes, such that the direction of attention is disengaged from the direction of gaze (Moore, et al., 2003; Posner, 2012). Covert and overt orienting are typically regarded as closely related processes (Findlay & Gilchrist, 2003; Hoffman & Subramaniam, 1995; Hutton, 2008; Rizzolatti, Riggio, & Sheliga, 1994). For example, it has been suggested that covert attention guides subsequent eye movements by providing a preview of potential objects or locations of interest that require more detailed foveal processing (Findlay & Gilchrist, 2003). Moreover, Hoffman and Subramaniam (1995) concluded that there was an obligatory link between overt and covert attention based on the finding that participants were unable to simultaneously execute an eye movement to one location and orient attention to a different location. One account for the close relationship between covert and overt attention was provided in the premotor theory of attention (Rizzolatti et al., 1994). This theory suggests that the preparation of an eye movement is responsible for covert shifts in visual attention and that the same neural circuitry underlies both overt and covert orienting. This theory is supported by fMRI data demonstrating considerable overlap in the brain regions recruited during overt and covert visual orienting (Corbetta et al., 1998; de Haan, Morgan & Rorden, 2008). For example, de Haan et al. (2008) found that a common fronto-parietal network was activated during overt and covert shifts of attention, which included bilateral activation in brain regions linked to the orienting network such as the frontal eye fields and the superior parietal lobes.

Overt or covert orienting and selection can be guided by stimulus-driven processes and/or goal-directed processes. Stimulus-driven processes involve the exogenous capture of attention by stimulus properties (Yantis, 1993). Throughout the review, we use the terms 'stimulus-driven' and 'exogenous' to indicate that the event triggering attentional selection is external to the individual and can conflict with task demands. Goal-directed processes involve the selection of information based on endogenous goals, beliefs and expectations (Yantis, 1993). We use the terms 'goal-directed' and 'endogenous' to indicate an internal event within the individual that triggers attentional selection on the basis of task demands. Corbetta and Shulman (2002) suggested that there were two fronto-parietal networks that controlled stimulus-driven and goal-directed visual attention. They suggested that the ventral fronto-parietal network is a stimulus-driven attentional system that is recruited when relevant, salient and previously unattended sensory events are detected. In contrast, the dorsal fronto-parietal network was proposed to be the goal-directed attentional system that was responsible for the endogenous selection of stimuli and responses. Corbetta and Shulman (2002) proposed that the two attentional systems interact such that the ventral network is able to interrupt the goal-directed functioning of the dorsal network in order to reorient attention to salient and unexpected stimuli. The ventral network is right lateralized and includes the temporo-parietal junction and ventral frontal cortex, whereas the dorsal network includes the frontal eye fields, intraparietal sulcus and superior parietal lobe (see Chica, Bartolomeo & Lupianez, 2013; Petersen & Posner, 2012).

Eye movement behaviors can provide important information about goal-directed and stimulus-driven selection processes because they allow measurement of endogenous and exogenous saccades. An individual will execute endogenous saccades towards stimuli that are required for and relevant to the ongoing task, whereas stimuli that capture attention irrespective of the observer's goals and expectations will elicit exogenous saccades (Godijn & Theeuwes, 2002). In a situation where a target and distractor appear simultaneously, for example, goal-directed processes are required to voluntarily inhibit an exogenous saccade to the distractor, thereby increasing the time taken to initiate an endogenous saccade to the target (Godijn & Theeuwes, 2002).

Theoretical Frameworks of Selective Attention to Threat in Anxiety

A number of accounts suggest that anxiety is characterized by vigilance for threat, where individuals with high levels of anxiety rapidly orient towards and allocate attentional resources to threatening stimuli in their environment, thus facilitating attentional processing in these regions (Beck & Clark, 1997; Williams, Watts, MacLeod, & Mathews, 1997). These accounts propose that vigilance for threat occurs in high trait anxious individuals, especially when concurrently experiencing high levels of state anxiety. For example, Mogg and Bradley (1998) proposed that there are two systems involved in anxiety-related stimulus processing: the valence evaluation system (VES) and the goal engagement system (GES). The affective valence of a stimulus is assessed automatically by the VES. If the output of this evaluation process indicates threat is present, then the function of the GES is to automatically allocate resources to the stimulus and assess current goals. The GES will continue to allocate resources to current goals if a low threat value has been assigned to the stimulus. Mogg and Bradley (1998) proposed that high levels of trait anxiety are associated with a lowered threshold in the VES for labeling a stimulus as threatening, leading to a bias in the stimulus evaluation process. Consequently, the GES directs attentional resources towards threat stimuli more frequently in individuals with high (vs. low) levels of trait anxiety. The framework suggests that, for all individuals, the VES correctly evaluates and labels stimuli as threatening when they have an objectively high threat value. In contrast, biases towards threats of an objectively mild threat value will be evident in individuals with elevated trait anxiety. Mogg and Bradley (1998) further proposed a pattern of vigilance-avoidance in anxiety, where the initial allocation of attention to threat is followed by avoidance (attention is directed away from threat at later stages of processing to regulate feelings of negative affect). This pattern of vigilance-avoidance is suggested to maintain anxiety, as it increases initial attention to threat and precludes habituation to these stimuli.

The proposed mechanism underlying vigilance for threat differs across theories of anxiety and attention. Mogg and Bradley (1998) suggested that vigilance for threat occurs as a consequence of a lowered threshold for evaluating an ambiguous (or mild threat) stimulus as threatening. In contrast, Williams et al., (1997) place less emphasis on the stimulus evaluation process and instead suggest that high and low anxious individuals differ in their allocation of attention in the presence of all threatening stimuli (mild or high threat); they proposed that individuals with high levels of anxiety direct attention towards threat and individuals with low levels of anxiety direct attention away from threat. More recently, it has been proposed that impairments in attentional control underlie vigilance for threat in anxiety and, additionally, lead to difficulties disengaging attention from threat and difficulties inhibiting processing of threatening distractors (Attentional Control Theory; Eysenck, Derakshan, Santos, & Calvo, 2007).

Attentional Control Theory (ACT; Eysenck et al., 2007) suggests that rapid orienting of attention to threat (e.g., vigilance) occurs as a result of an increased influence of the stimulus-driven attentional system in individuals with high levels of trait anxiety. This theory also proposes that trait anxiety is associated with a decreased influence of the goal-directed attentional system, leading to impairments in functions related to attentional control such as inhibition (e.g. resisting distractor interference), attentional shifting (moving between multiple tasks) and updating information in working memory. These impairments are suggested to be particularly pronounced in the presence of threatening distractors because individuals with high levels of anxiety are unable to inhibit processing of task-irrelevant threat, leading to a loss of attentional focus and impaired performance on task-relevant activities. The notion of impaired attentional control and difficulties inhibiting threat processing are consistent with attention maintenance theory (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo & Dutton, 2002), which suggests that increased state and/or trait anxiety is characterized by slower attentional disengagement from threat (vs. non-threat) stimuli. This theory proposes that the threat bias occurs due to increased dwell time on threat stimuli (i.e., difficulties inhibiting and shifting attention away from threat), rather than rapid initial orienting towards threat.

Empirical Evidence for Selective Attention to Threat in Anxiety

The following sections review the empirical evidence separately for the two proposed components of the selective attentional bias to threat: vigilance and attention maintenance. Each section begins with a review of the traditional RT paradigms that have been widely used to consider selective attention to threat. We then outline the ways in which eye tracking techniques have further explicated these attentional processes. The findings are presented across samples with different clinical anxiety disorders and in subclinical samples with high levels of self-reported anxiety; this approach is based on research suggesting that these groups do not differ in the magnitude of the threat bias. Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, and van IJzendoorn (2007) conducted a meta-analysis based on three paradigms linked to selective attention (the dot probe, spatial cueing and Stroop paradigm) and found that there was a significant bias towards threat in individuals with anxiety, regardless of their clinical status (clinical or subclinical) or type of clinical anxiety disorder (generalized anxiety disorder, obsessive compulsive disorder, panic disorder, post-traumatic stress disorder, social phobia, simple phobia).

Vigilance. Vigilance for threat has predominantly been assessed using the dot probe paradigm. This paradigm involves the presentation of stimulus pairs consisting of an emotional stimulus (threat or positive) and a neutral stimulus. The stimulus pair is replaced by a dot probe that appears in the location of the previous neutral or emotional stimulus and participants are asked to respond to the probe (i.e., to indicate its location or identity). If an individual selectively orients their attention towards the threat item in a threat-neutral stimulus pair, then RTs will be faster when the dot probe appears in the same location as the threat (vs. the neutral) stimulus (MacLeod, Mathews, & Tata, 1986).

Using this paradigm, findings of vigilance for threat stimuli have been demonstrated in individuals with high trait anxiety (Bradley, Mogg, Falla, & Hamilton, 1998), high state anxiety (Mogg, Bradley, DeBono, & Painter, 1997), a clinical diagnosis of generalized anxiety disorder (GAD) (MacLeod et al., 1986), a clinical diagnosis of social phobia (Mogg, Philippot, & Bradley, 2004) and high fear of spiders (Mogg & Bradley, 2006). These findings are reliably observed when the stimulus pairs are presented for a short duration (e.g., up to 500 ms; (Bradley et al., 1998; Mogg & Bradley, 2006; Mogg et al., 1997; Mogg et al., 2004), but are less reliable when the stimulus pairs are presented for longer durations (e.g., over

1250 ms; (Bradley et al., 1998; Mogg & Bradley, 2006; Mogg et al., 2004). Despite indications that the selective attentional bias to threat occurs at a relatively early stage of processing, it has been highlighted that the RT dot probe paradigm can only be used to assess the attentional bias to threat at the snapshot of time in which the probe occurs (Yiend, 2010). It is possible that multiple attentional shifts can occur within 500 ms of stimulus presentation, however the RT dot probe paradigm cannot elucidate whether attention was allocated to the threatening stimulus before or after the onset of the probe (Yiend, 2010). Eye movement measures have proved useful in addressing this limitation because they provide an online measure of orienting responses from the onset until the offset of threat-neutral stimulus pairs (i.e., prior to the probe) in this paradigm.

Eye tracking studies have also reported findings consistent with vigilance for threat in anxiety (see Armstrong & Olatunji, 2012). A number of studies have measured eye movements concurrently whilst participants completed a typical RT dot probe paradigm. These studies measured eye movements continuously from the onset of the threat-neutral stimulus pair until the manual response. A bias in initial orienting to threat stimuli is inferred from a higher proportion of first fixations or initial saccades landing on a threat (vs. non-threat) stimulus, and shorter latencies between the onset of a display and the first fixation on a threat (vs. non-threat) stimulus. These studies indicate that, in comparison with non-anxious control participants, there is a bias in initial orienting to: angry faces in individuals with GAD (Mogg, Millar, & Bradley, 2000) and social phobia (Stevens, Rist, & Gerlach, 2011); angry and fearful faces in individuals with high trait anxiety (Mogg, Garner, & Bradley, 2007); negative faces (angry and sad) in individuals with high social anxiety (Bradley, Mogg, & Millar, 2000); and angry and happy faces in individuals with high fear of negative evaluation when experiencing current social-evaluative stress (i.e., where participants anticipated that they would need to deliver a speech following the experiment; see Garner, Mogg, & Bradley, 2006). The broad conclusion drawn from these studies is that there is an attentional bias in initial orienting to threat in anxiety, supporting the proposition that anxious individuals selectively attend to threat.

Similar findings have been reported in eye tracking studies using free-viewing tasks. These studies have typically involved the simultaneous presentation of two or four emotional or neutral pictures for 2 -60 seconds and participants are simply asked to look at the pictures in whichever way they choose. Eye movements are measured continuously from the onset until the offset of the images, providing an online measure of attention over a longer timescale compared with the dot probe paradigm[1]. An initial bias in orienting responses is inferred from a higher probability of first fixations, or a higher proportion of total fixations or total viewing time directed towards a threat (vs. neutral) stimulus within the first 500 ms or 1000 ms of stimulus presentation. Using these paradigms, a bias in initial orienting has been observed for angry and happy faces in individuals with a heightened fear of negative evaluation (Wieser, Pauli, Weyers, Alpers, & Muhlberger, 2009) or social phobia (Gamble & Rapee, 2010); positive and threatening pictures in individuals with high levels of trait anxiety (Calvo & Avero, 2005); spider pictures in spider fearful individuals (Rinck & Becker, 2006); and contamination threat pictures for individuals with high contamination fear (Armstrong, Sarawgi, & Olatunji, 2012).

It is possible that positive findings of vigilance for threat rely on the specific experimental conditions that occur in the dot probe and free viewing paradigms, such that results reflect a preference to allocate attention to threat when presented with simple visual

[1] The longer stimulus durations in free-viewing tasks have typically been used to consider the theoretical proposition that anxiety is characterized by initial vigilance towards threat, followed by attentional avoidance (Mogg & Bradley, 1998). Attentional avoidance is recognized to be a strategy actively employed at later stages of cognitive processing (e.g., from approximately 500 ms onwards after stimulus onset; e.g., Hofmann, Ellard, & Siegle, 2012) that works to regulate negative affect (Cisler & Koster, 2010). While we include theories and research that incorporate the notion of attentional avoidance, this concept is not central to our discussion of anxiety and attention. Therefore, we focus our discussion only on the initial orienting responses in free-viewing tasks.

displays in which there are few items and it is predictable that no more than one of these items will be threatening. The evolutionary purpose of selective attention is, however, to ensure that the limited capacity cognitive system selects high priority signals for further processing from a large array of competing environmental stimuli (Dolan & Vuilleumier, 2003). A selective attentional mechanism is of limited value if it only operates in simple visual environments, where few items compete for attentional resources. If selective attention to threat is a fundamental attribute in anxious individuals, then it should also be evident in complex visual environments that include numerous stimuli in a variety of locations. This proposition can be assessed with eye movement measures by considering whether individuals with high levels of anxiety are able to direct their initial orienting response (e.g., the first fixation) to a threatening stimulus rather than the numerous competing stimuli that appear in complex visual displays.

Consistent with this proposition, Armstrong and Olatunji (2012) found that individuals with higher levels of anxiety fixated threatening targets more rapidly compared with non-anxious individuals in visual search studies with display sizes ranging from 7 to 20 items. Crucially, this orienting bias to threat in anxious individuals was not evident on the earliest eye movement indicators, such as the location of the first fixation in a trial. In other words, anxious and non-anxious individuals did not differ in the frequency with which the first fixation landed on a threat target. Armstrong and Olatunji (2012) suggested that the absence of an initial orienting bias in the visual search (vs. dot probe and free viewing) studies might be explained by the increased perceptual load (e.g. more display items) and greater stimulus eccentricity associated with this paradigm, indicating that the orienting bias in anxiety may be capacity-limited.

A recent eye tracking study using an alternative complex experimental task also found no evidence of an initial orienting bias to threat in anxiety. Huijding, Mayer, Koster, & Muris

(2011) recruited individuals with high or low fear of spiders and employed a change detection paradigm in which participants were presented with pictures of household scenes for 10 seconds. Participants were informed that no target stimulus, one target stimulus or two target stimuli could appear slowly in the image and that they should press a button when they noticed a change in the image. Eye movements were measured concurrently. The target stimuli were neutral (a crossed knife and fork), negative (a skull with cross bones) or spider-relevant (a spider). The results indicated that manual detection responses did not differ between a high and low spider fearful group for any type of target stimulus. However, when considering the time taken and number of non-target fixations between the onset of the first target and the first target fixation, they found that individuals with a high (vs. low) fear of spiders took significantly longer to fixate a spider target and made more non-target fixations. This effect was not observed if the first target was neutral or negative. This finding is compatible with threat avoidance, but inconsistent with rapid initial orienting of overt attention to threat.

To summarize, a consistent and replicable literature has emerged using the dot probe and free viewing paradigms which supports the proposition that individuals with high levels of anxiety are vigilant by rapidly allocating attention to threatening stimuli. The generalizability of these findings has been challenged by the mixed results reported from studies using more complex experimental paradigms. If vigilance for threat in anxiety is closely tied to the experimental conditions in the dot-probe or free-viewing paradigms, then it is possible that this effect is specific to situations in which there are few competing visual stimuli and where prior learning indicates that there is a high probability that one threat stimulus will appear in a small number of pre-determined locations. The literature has not yet established whether findings of vigilance for threat generalize to experimental conditions that more closely resemble real-world situations; for example, conditions in which there are a large array of competing visual stimuli, where the appearance of a threat stimulus is unexpected and where the number, location and timing of threat stimuli is unpredictable.

Attention maintenance. The spatial cueing paradigm has been used as a method for distinguishing between rapid engagement with threat (e.g., vigilance) and delayed disengagement from threat (e.g., attention maintenance). It involves the presentation of a threatening, positive or neutral peripheral cue, which is either congruent (valid cue) or incongruent (invalid cue) with the location of a subsequent target. The participant is asked to respond to the target (i.e., indicate its identity or location). The rationale underlying the paradigm is that valid cues should facilitate performance (i.e., leading to faster RTs in response to the target) and invalid cues should disrupt performance (i.e., leading to slower RTs in response to the target; see Posner, Snyder, & Davidson, 1980). It has been argued that rapid engagement with threat stimuli would be reflected in faster RTs to the target following valid threat (vs. valid non-threat) cues. Conversely, delayed disengagement from threat would be reflected in slower RTs to the target following invalid threat (vs. invalid non-threat) cues (see Fox et al., 2001, 2002).

There is growing evidence from the spatial cueing paradigm to show that individuals with high levels of anxiety are slow to disengage attention from threat. Findings of delayed disengagement have been observed for 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). Furthermore, there is evidence to indicate that difficulties disengaging from threat are especially pronounced in individuals reporting high levels of trait anxiety in conjunction with low levels of attentional control (Derryberry & Reed, 2002). These studies did not provide any evidence to support the proposition of rapid engagement with threat in individuals high in state or trait anxiety or individuals with social phobia.

Koster and colleagues (Koster, Crombez, Verschuere, & De Houwer, 2006; Koster, Verschuere, Crombez, & Van Damme, 2005) similarly proposed that performance on the dot probe task could result from either rapid engagement with threat (when a 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). To distinguish between these explanations, they modified the paradigm by measuring RTs in trials containing neutral-neutral stimulus pairs and comparing these to RTs in trials containing threat-neutral stimulus pairs. They argued that rapid engagement with threat would be reflected in faster RTs 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. In contrast, slowed disengagement from threat would be reflected in slower RTs when the probe replaced the neutral stimulus in the threat-neutral condition compared with the neutral-neutral condition. Using this rationale, Koster et al. (2006) found results consistent with delayed disengagement from threat in high trait anxious individuals, but no evidence of rapid engagement with threat.

A number of eye movement studies have addressed a similar research question. However, rather than presenting threatening stimuli as task-relevant cues that predict the location of a target, these studies have extended the spatial cueing and dot probe paradigms by presenting threatening stimuli as distractors that are spatially distinct from a target stimulus. These methods distinguish between attentional capture by task-irrelevant threat (vigilance) and delayed disengagement from task-irrelevant threat (attention maintenance). Here, the concept of attentional capture is very similar to rapid engagement; however the critical distinction is that attentional capture is regarded as an impairment because it relates to the negative impact of task-irrelevant threat, whereas rapid engagement is typically considered in relation to facilitated attention. Thus, while RT findings from the spatial cueing paradigm indicate that anxiety does not affect engagement with a task-relevant cue, it remains possible that anxiety is associated with attentional capture by task-irrelevant distractors.

Initial studies in this area used complex displays with 8 to 16 stimuli and measured eye movements concurrently during an RT visual search task (Miltner, Krieschel, Hecht, Trippe, & Weiss, 2004; Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005). The emphasis was on assessing the detrimental impact of threat (vs. non-threat) distractors on target detection. Miltner et al. (2004), for example, 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 key press response when they detected a pre-specified target. The results showed 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). They also reported that 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. These findings suggest that feared distractors captured overt attention and interfered with ongoing performance (as indexed by manual detection responses) in anxious individuals.

In a related visual search study, Rinck et al. (2005) found that spider fearful individuals fixated on spider distractors for a longer duration and were slower to detect a target presented amongst spider distractors compared with non-fearful individuals. In contrast, there was no significant difference in gaze duration or the time taken to detect the target between the fearful and non-fearful groups when the distractors were butterflies or beetles. The authors concluded that individuals with high levels of anxiety were slower to disengage their attention from feared objects. However, these findings were not replicated in a visual search study by Derakshan and Koster (2010), where eye movement measures indicated that trait anxiety was not associated with delays in disengaging visual attention from threatening distractors (angry faces).

To summarize, studies that have used RT paradigms to disentangle the vigilance and attention maintenance hypotheses have frequently found evidence to support the latter with consistent findings of delayed disengagement from threat. However, eye tracking studies that have focused more specifically on the detrimental impact of threatening distractors have been equivocal in this respect, but have provided some evidence to suggest that anxiety is associated with two distinct forms of impaired attention: attentional capture by threat (Miltner et al., 2004) and delayed disengagement of foveal vision from threat (Rinck et al., 2005).

Hypervigilance and Threat Detection in Anxiety

We argue that a significant limitation in the existing literature on anxiety is the assumption that selective attention to threat is closely linked to hypervigilance and enhanced threat detection. While selective attentional processes are associated with the orienting network, hypervigilance is more readily linked to the alerting network proposed by Posner and colleagues (Fan et al., 2005; Posner, 2012; Posner & Rothbart, 2007). Hypervigilance serves to ensure that the cognitive system is alert and in a state of readiness to detect high priority signals that have the potential to threaten survival (Beck & Clark, 1997; Dolan & Vuilleumier, 2003). Posner and Peterson (1990) suggested that the alerting network makes it possible to respond to high priority stimuli by sustaining activation in the cognitive system over extended periods of time (i.e., hypervigilance) or in response to warning signals (i.e., phasic alertness). Diffuse brain regions have been associated with this alerting network, including the locus coeruleus and the right frontal and parietal cortex (Fan et al., 2005; Posner, 2012; Posner & Peterson, 1990; Posner & Rothbart, 2007).

While several cognitive theories highlight hypervigilance and rapid detection of threat as important components of anxiety (e.g., Beck, Emery, & Greenberg, 2005; Eysenck, 1992; Rapee & Heimberg, 1997), the model proposed by Eysenck (1992) is the only theoretical account to make differential predictions about the relationship between anxiety and attention before and after threat detection. Consistent with other theoretical frameworks, Eysenck (1992) proposed that high trait anxious individuals selectively narrow attention onto threatening (vs. neutral) stimuli following threat detection. Prior to detection, Eysenck (1992) suggested that individuals with high levels of trait anxiety are hypervigilant[2] for threat in order to enhance threat detection, leading to (1) rapid scanning of the environment for threat with a narrow focus of attention and numerous eye movements or (2) the maintenance of a broad focus of attention until a threatening stimulus is encountered. This theoretical model raises the possibility that atypical attentional processes are not restricted to situations in which a threat is present, but can occur pervasively before and after threat detection. For example, ACT (Eysenck et al., 2007) suggests that impairments in attentional control occur in the presence and absence of threat and that in its absence anxious individuals remain hypervigilant for threat, leading to increased distraction from task-irrelevant stimuli and reduced attentional focus on ongoing tasks. These impairments in attentional control occur because cognitive capacity is dedicated to scanning the environment for threat rather than carrying out task-relevant activities (Beck et al., 2005).

The following section reviews empirical evidence consistent with enhanced threat detection in anxiety based on RT measures from the visual search paradigm. We then highlight the utility of eye movement studies in assessing the proposition that anxiety is

[2] Beck et al. (2005) also discussed hypervigilance; they proposed that it reflects cognitive mobilization in response to the possibility of threat and impending danger that prepares an individual for a defensive reaction. Similarly, in their model of social phobia Rapee and Heimberg (1997) suggested that, after detecting an audience, individuals with social phobia are hypervigilant for signs of negative evaluation (e.g. frowns), anger and aggression.

characterized by hypervigilance for threat, leading to enhanced threat detection and increased distraction from task-irrelevant stimuli across the visual field.

Empirical Evidence for Superior Threat Detection in Anxiety

The majority of the literature surrounding threat detection in anxiety has utilized the visual search paradigm (Bar-Haim, et al. 2007; review by Donnelly, Hadwin, Menneer, & Richards, 2010). In the visual search paradigm, participants are asked to search for and indicate the presence or absence of a target that is 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 and calculate the gradient of the search slope (where RTs are regressed against set size). Search slopes can be used to consider search efficiency, where shallow slopes represent an efficient search and indicate that set size has no impact (or a small impact) on the speed of detecting the target (Duncan & Humphreys, 1989; Wolfe, 1998). Inefficient search is reflected in a steep search slope gradient, where the speed of detecting the target item decreases as set size increases. It has been suggested that anxiety might moderate a number of parameters involved in searching for and deciding upon the presence of a threat (e.g., information processing rates and decision thresholds; see Donnelly et al., 2010). These effects would lead to faster RTs and shallower slopes when searching for threat (vs. non threat) in individuals with high (vs. low) levels of anxiety.

Studies employing RT measures have found 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 specific stimuli (Flykt & Caldara, 2006; Öhman, Flykt, & Esteves, 2001; Rinck et al., 2005; Soares, Esteves, Lundqvist, & Öhman, 2009). There is also evidence to suggest that social anxiety and trait anxiety are associated with greater speed and accuracy in searching for and detecting the presence of angry target faces (Gilboa-Schechtman, Foa, &

Amir, 1999; Byrne & Eysenck, 1995; Juth, Lundqvist, Karlsson, & Öhman, 2005). Further studies have varied set size in order to assess the effect of anxiety on search efficiency as indexed by the gradient and intercept of the search slope (Eastwood et al., 2005; Matsumoto, 2010). These studies found that anxiety was linked to greater efficiency in detecting the presence of an angry face in high (vs. low) trait anxious adults (Matsumoto, 2010) and adults with social phobia and panic disorder compared with control participants or individuals with OCD (Eastwood et al., 2005).

Matsumoto (2010), for example, asked participants to indicate the presence or absence of a discrepant face in displays containing 4, 8 or 12 schematic faces. 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 the gradient of the search slope was significantly shallower for angry target faces compared with happy target faces in high (but not low) trait anxious individuals in the context of neutral distractors.

In isolation, within-group effects of this type do not necessarily imply that anxious individuals use the threatening content of the target to guide search. Some researchers have argued that this finding indicates that anxious individuals are sensitive to feature differences between angry and happy faces (e.g., the angle of the eyebrows or mouth; see Cave & Batty, 2006) and it raises the possibility that anxiety would be associated with similar sensitivities to feature differences for any visual stimuli, even those that are unrelated to threat. It is also difficult to determine whether the within-group effect in anxious individuals is driven by a heightened ability to use visual features associated with angry faces, a reduced ability to use visual features associated with happy faces, or both.

Matsumoto (2010) also found that the search slope for the angry faces was shallower in the high trait anxious group compared with the low trait anxious group. Between- group effects of this type are important in indicating that an individual's level of anxiety specifically affects search for threat. The typical explanation for this effect is that anxious individuals are more able to use the threatening content of a stimulus to guide search. An alternative explanation is that anxious individuals are more able to use features associated with threat to guide search due to increased motivation or practice in finding threatening stimuli (Cave & Batty, 2006).

Taken together, the results of visual search studies typically suggest that there is enhanced threat detection in anxiety. These findings are relatively consistent across clinical and sub-clinical populations experiencing different types of anxiety (e.g. spider phobia, social anxiety, trait anxiety, GAD; see also Cisler, Bacon & Williams, 2009). However, the mechanisms that underlie this facilitated performance remain unclear. In particular, few studies have explored the hypervigilance hypothesis (e.g., Eysenck, 1992); that anxiety is associated either with a broad distribution of attention or with rapid scanning of the environment with a narrow focus of attention.

Hypervigilance: Attentional Broadening and Excessive Scanning.

Few eye tracking studies have been conducted to assess the hypothesis that anxiety is characterized by hypervigilance, where individuals either excessively scan the visual environment for threat with numerous eye movements or maintain a broad focus of attention by executing few eye movements (Freeman, Garety, & Phillips, 2000; Horley, Williams, Gonsalvez, & Gordon, 2004). Horley et al. (2004) found evidence of excessive scanning in individuals with social phobia in a free-viewing task, where participants were presented with a picture of a neutral, sad, angry or happy face for 10,000 ms. They found that the scanpath length (the total distance covered by the eyes) was greater for individuals with social phobia (vs. controls) when viewing angry or neutral faces. They concluded that this finding reflected hypervigilance for signs of negative social evaluation in individuals with social phobia. In contrast, Freeman et al. (2000) found no evidence of excessive scanning or enhanced threat detection in a group of individuals with GAD. Taken together, the findings from these studies are equivocal with respect to the hypothesis that anxious individuals excessively scan the environment for threat (Eysenck, 1992).

One further eye tracking study considered the possibility that anxiety is associated with enhanced threat detection and it aimed to assess whether this occurred in the context of a broad focus of attention or excessive scanning (Richards, Hadwin, Benson, Wenger, & Donnelly, 2011). Using a redundant signals paradigm, Richards et al. (2011) instructed participants to indicate the presence or absence of a target face (angry or happy) with a keypress response and eye movements were measured concurrently. Displays contained two items: two neutral faces in the target absent condition; one emotional target (angry or happy) and one neutral face in the single target condition; two emotional targets (either two angry or two happy faces) in the redundant target condition. Presentation of only one target was required for a target present response. The results showed that trait anxiety was linked to increased processing capacity to detect multiple (vs. single) angry faces. Individuals with higher levels of trait anxiety also executed fewer eye movements regardless of the presence, absence or expression of the target. Richards et al. (2011) concluded that anxiety affects the efficiency of the threat detection system such that it is possible for anxious individuals to more readily accumulate threatening information from multiple locations across the visual field, thereby improving threat detection in the presence of multiple (vs. single) threats. Furthermore, they suggested that the tendency for anxious individuals to maintain a broad focus of attention by executing fewer eye movements is likely to facilitate this detection process.

Taken together, evidence to support the notion that hypervigilance involves excessive scanning (i.e. numerous eye movements) in anxiety is equivocal (e.g., Freeman et al., 2000;

Horley et al., 2004). However, some evidence does support the proposition that individuals with elevated anxiety adopt a broad distribution of attention and demonstrate increased processing capacity to detect multiple threats within this attended region (Richards et al., 2011).

Monitoring the environment for threat facilitates threat detection; however, it also requires cognitive capacity (Beck et al., 2005) and, therefore, leads to increased distraction from task-irrelevant stimuli and reduced attentional focus on ongoing tasks (i.e. impaired attentional control; Eysenck et al., 2007). Recent eye tracking research has aimed to understand the processes underlying impaired attentional control in anxiety by using modified versions of traditional eye tracking tasks such as the oculomotor capture paradigm (Gerdes, Alpers, & Pauli, 2008), anti-saccade paradigm (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Reinholdt-Dunne et al., 2012; Wieser, Pauli, & Muhlberger, 2009) and remote distractor paradigm (Richards, Benson, & Hadwin, 2012). We suggest that findings from these studies are consistent with the impairments in attention predicted by the hypervigilance hypothesis.

The oculomotor capture, antisaccade and remote distractor paradigms involve the participant suppressing an exogenous saccade to a task-irrelevant stimulus (threat or non-threat) and voluntarily executing an endogenous saccade to a target stimulus or location. If anxiety is associated with attentional capture by threat, then anxious individuals should be unable to suppress exogenous saccades to task-irrelevant threat. If individuals with high levels of anxiety find it difficult to disengage overt attention from threat, then anxiety should be associated with a delay in voluntarily executing endogenous saccades away from task-irrelevant threat presented within foveal vision. If anxiety is characterized by a broad focus of attention, then the delay in voluntarily executing endogenous saccades towards a target should occur irrespective of whether the task-irrelevant threat is presented within or outside foveal vision.

In a typical oculomotor capture task (e.g., Theeuwes, Kramer, Hahn, & Irwin, 1998), participants are presented with displays containing approximately six grey circles in peripheral locations. On every trial, all but one of the circles changes color from grey to red. Participants are required to execute an eye movement towards the color singleton and provide a manual response to discriminate the letter presented inside the color singleton. On some of the trials, an additional red circle (a task-irrelevant abrupt onset) appears simultaneously with the color change. Theeuwes et al. (1998) found that exogenous saccades were made to task-irrelevant abrupt onsets prior to the endogenous saccade towards the target on 30-40% of the trials. They concluded that attention was involuntarily captured by the abrupt onset stimuli.

Gerdes et al. (2008) modified the oculomotor capture paradigm by manipulating the picture presented inside the abrupt onset such that it contained either no picture or a picture of a spider, mushroom or flower. They found that the percentage of error fixations (i.e., first fixations on the abrupt onset due to an inability to suppress an exogenous saccade) was significantly higher in a group with a clinically significant spider phobia compared with a control group, but this effect was not threat-specific and occurred regardless of whether the abrupt onset contained a picture of a spider, mushroom or flower or contained no picture. The duration of error fixations on an abrupt onset containing a spider picture was significantly longer in the spider phobic group compared with the control group (i.e., indicating a delay in executing an endogenous saccade away from threat) and this effect was not observed for abrupt onsets containing other stimuli. Gerdes et al. (2008) suggested that this pattern of eye movement behavior was indicative of “unspecific hypervigilance” followed by a “specific disengagement deficit” (p. 184). That is, attention was captured by all types of abrupt onset in individuals with spider phobia because it was possible that any of these stimuli could contain a spider. In contrast, delays in disengaging attention from the abrupt onset were specific to threatening stimuli in individuals with spider phobia.

Similar findings of non-specific hypervigilance and threat-specific difficulties in inhibition have been observed using the anti-saccade paradigm (Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Wieser, Pauli, & Muhlberger, 2009). Here, participants are presented with a peripheral visual cue, which they are asked to look towards (prosaccade condition) or away from (antisaccade condition) as quickly as possible. The antisaccade condition requires the inhibition of an exogenous prosaccade to the cue and volitional programming of an endogenous antisaccade to the mirror position. Accurate first saccade latencies are typically slower in the antisaccade (vs. prosaccade) condition. This paradigm has been modified by presenting peripheral cues that are either threatening or non-threatening (e.g., Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Wieser, Pauli, & Muhlberger, 2009). In the antisaccade condition, attentional capture by threat is reflected in a higher proportion of exogenous saccades to a threatening (vs. non-threatening) cue and impaired inhibition of threat is reflected in longer antisaccade latencies (endogenous saccades) when the peripheral cue is threatening (vs. non-threatening).

Using this rationale, Derakshan et al. (2009) presented face cues (angry, happy or neutral) in peripheral locations and found that the latency of the accurate first saccades in the antisaccade condition were significantly longer in a high (vs. low) trait anxious group when the cue was an angry (but not happy or neutral) face. Anxiety did not affect the error rate in the antisaccade condition (as indexed by exogenous saccades to the cue). These findings indicate that there was a delay in inhibiting processing of threat stimuli in anxious individuals, but provide no evidence for attentional capture by threat. This finding was replicated by Reinholdt-Dunne et al. (2012). In contrast, Wieser, Pauli, and Muhlberger (2009) found that anxiety did not affect the latency of the first saccade in the antisaccade condition; however, individuals high in fear of negative evaluation made significantly more errors in the antisaccade condition compared with control participants for all facial expressions (angry, happy, fearful, sad and neutral). They concluded that there was a general attentional control deficit in anxiety. These studies provide some evidence to indicate that the impairment in attentional control is associated with a specific difficulty in inhibiting threat processing even if threat stimuli are presented outside foveal vision (Derakshan et al., 2009; Reinholdt-Dunne et al., 2012), or that anxiety is associated with non-specific hypervigilance (Wieser, Pauli, & Muhlberger, 2009).

The remote distractor paradigm requires participants to execute a saccade to a target as quickly as possible and to ignore the presence of a simultaneously presented distractor that occurs for the majority of the trials (Benson, 2008; Walker, Deubel, Schneider, & Findlay, 1997). Walker et al. (1997) found that the presence of a distractor (a circle) delayed the latency of the endogenous saccade to a target (a cross) by 30-40 ms when the distractor was centrally located and by 10-30 ms when the distractor was presented in the contralateral visual hemifield to the target (compared with trials in which no distractor was present). Furthermore, exogenous saccades to a distractor typically occur in approximately 10-30% of the trials in this paradigm (Benson, 2008). This paradigm has been modified to distinguish between the different components of impaired attentional control in anxiety by presenting threat (vs. non-threat) distractors in central, parafoveal or peripheral locations (Richards et al., 2012). Here, attentional capture by threat is reflected in a higher proportion of inaccurate exogenous saccades to threat (vs. non-threat) distractors. Delayed disengagement from threat is reflected in a greater delay in executing endogenous saccades to the target in the presence of a central threat (vs. non-threat) distractor. A more pervasive difficulty in inhibiting threat across the visual field is reflected in a greater delay in executing endogenous saccades to the target in the presence of central, parafoveal and peripheral threat (vs. non-threat) distractors.

Richards et al. (2012) instructed participants to look at a target (a square or a diamond), presented in a parafoveal or peripheral location, as quickly and accurately as possible and to indicate its identity with a keypress response. The target was either presented alone or with a task-irrelevant distractor face (angry, happy or neutral). The results showed no evidence of attentional capture by threat; anxiety was not associated with an inability to suppress exogenous saccades to angry distractors. However, trait anxiety was positively associated with the magnitude of the delay in executing endogenous saccades to the target in the presence of angry (but not happy or neutral) distractors, and this effect was consistent when the angry face was presented in central, parafoveal or peripheral locations. Richards et al. (2012) concluded that the findings indicated both impaired attentional control and hypervigilance for threat in anxiety; individuals with increased trait anxiety were able to extract threatening information from a broad attentional beam and this led to greater interference from task-irrelevant threat presented in a variety of locations across the visual field. This study demonstrated that the tendency to remain hypervigilant for threat across the visual field disrupts attentional control and leads to pervasive difficulties in focusing attention on current tasks (Beck et al., 2005; Eysenck et al., 2007).

To summarize, findings from these studies are consistent with impairments in attentional control predicted by the hypervigilance hypothesis (Eysenck, 1992; Eysenck et al., 2007), indicating that anxious individuals monitor the environment for threat and are unable to suppress interference from threatening distractors. While eye tracking studies do not support the notion of specific attentional capture by threat in anxiety (Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Richards et al., 2012), the evidence suggests that there may be non-specific hypervigilance in anxiety as reflected in increased attentional capture by task-irrelevant threat and non-threat stimuli (Gerdes et al., 2008; Wieser, Pauli, & Muhlberger, 2009). The findings also indicate that there is a delay in executing endogenous saccades to a target in the presence of task-irrelevant threat in anxious individuals (Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Richards et al., 2012) where this impaired inhibition occurs for threats presented across a broad region of the visual field (Richards et al., 2012).

Theoretical Implications

Recent studies using eye movement methods have provided new insight into the threat-related attentional bias in anxiety. Collectively, these studies have started to explore the typical features of eye movement behavior in anxious individuals in order to assess the characteristics of the attentional bias under different experimental conditions. We suggest that previous findings and future studies of eye movement behavior could be used to test and distinguish between different theoretical models of anxiety and attention. Although attentional biases to threat in anxiety have typically been regarded as covert attentional processes, our emphasis on overt visual orienting is based on the view that a dissociation between covert and overt attention is unlikely to occur when an individual is presented with a complex visual scene that places demands on both the capacity of the cognitive system and the physiological constraints of the visual system.

Recent reviews (Armstrong & Olatunji, 2012; Weierich, Treat, and Hollingworth, 2008) have also highlighted the potential utility of eye tracking measures in understanding attentional processing in anxiety and, in particular, have suggested that these measures can be used to distinguish between two key components of the selective attentional bias: vigilance (i.e., initial orienting to threat) and attention maintenance (i.e., difficulties disengaging from threat). However, we argue that eye movement measures can also be used to address broader theoretical hypotheses that extend beyond the notion of selective attention to threat. In particular, we suggest that these measures can also be used to consider the hypothesis that anxiety is characterized by hypervigilance for threat.

Based on our review of the empirical research across different paradigms and measurement techniques, we present a framework (Figure 1) that regards selective attention and hypervigilance for threat as separable processes which can be distinguished by their evolutionary purpose, their underlying mechanisms, the environmental or experimental conditions in which they occur, the patterns of facilitated and impaired attention that they generate, and the predicted pattern of associated eye movement behaviors. Our proposition that selective attention to threat and hypervigilance for threat are separable is supported by recent evidence suggesting that these processes can be distinguished by their neural circuitry and the type of anxiety that they elicit. In line with previous theories of anxiety and attention, the framework we present reflects threat processing in individuals with high levels of trait anxiety or clinical levels of anxiety, especially when concurrently experiencing high levels of state anxiety. We regard anxiety as a dimensional construct in which high levels of trait anxiety are a risk factor in the development of anxiety disorder (see also Eysenck, 1992); therefore, we argue that the framework is also relevant to understanding threat processing in individuals with different forms of clinical anxiety disorder. However, given the small number of studies considering hypervigilance for threat in anxiety (e.g., attentional broadening, excessive scanning and impaired inhibition), we note that an important direction for future research will be to consider the extent to which hypervigilance varies as a function of clinical status and type of clinical anxiety disorder.

Figure 1 highlights that hypervigilance for threat and selective attention to threat serve distinct purposes. The purpose of hypervigilance is to remain in a state of readiness for the possible occurrence of threat in order to ensure that it is detected rapidly (e.g., Eysenck, 1992). Selective attention to threat ensures that threat stimuli receive processing priority at the expense of non-threat stimuli (e.g., Mogg & Bradley, 1998; Williams et al., 1997). Both processes are adaptive evolutionary functions that serve to protect individuals from impending or present danger. However, these processes become maladaptive in anxious individuals because they are excessively sensitive to threat (e.g., Beck & Clark, 1997).

The mechanisms that underlie hypervigilance and selective attention are directly opposed and, therefore, are unlikely to occur simultaneously (see Figure 1). Hypervigilance would be accomplished either by broadening attention or by rapidly scanning the environment with a narrow focus of attention (Eysenck, 1992); both approaches would make it possible to monitor a large region of the environment for threat. In contrast, selective attention would be accomplished by narrowing attention onto threat stimuli (e.g., Mogg & Bradley, 1998; Williams et al., 1997). This approach would ensure that a small region of the environment received processing priority such that there was detailed processing of threat stimuli and minimal processing of non-threat stimuli. We propose that the process of monitoring for threat (via attentional broadening or excessive scanning) and the process of narrowing attention onto a threatening stimulus would be associated with increased activation in dissociable regions of the brain and would elicit different types of anxiety. Specifically, selective attention to threatening stimuli would elicit transient anxiety and be associated with increased activation in the amygdala; hypervigilance for threat would elicit sustained anxiety and be linked to increased activation in the bed nucleus of the stria terminalis (Somerville et al., 2013; Somerville, Whalen, & Kelley, 2010).

There is considerable evidence to suggest that subcortical structures (e.g., pathways between the amygdala and thalamus) are important components of the neural circuitry involved in the early processing of threatening stimuli (Davis & Whalen, 2001; LeDoux, 1998) and that a heightened amygdala response is likely to underlie selective attention to threat in anxiety (Hofmann, et al. 2012). Findings related to heightened amygdala activation during threat processing in anxious individuals may occur as a result of the frequent use of experimental paradigms that present transient stimuli for a short duration of time (e.g., the appearance of a threatening face or threatening word for less than 1000 ms). It has been argued that stimuli of this type will elicit transient anxiety, which occurs for a brief duration in response to a discrete threat stimulus (Somerville et al., 2013, 2010). Transient anxiety most clearly resembles state anxiety and, therefore, it is likely that the interaction between high trait anxiety and high state anxiety that is proposed in theoretical models of anxiety will be particularly evident in studies that assess selective attention to threat using transient threat stimuli.

Somerville and colleagues have recently drawn an important distinction between transient anxiety and sustained (or anticipatory) anxiety and found that the latter is not associated with heightened activation in the amygdala. Sustained anxiety is elicited in situations where an individual monitors for and anticipates threat (e.g., hypervigilance), particularly under conditions where the timing of this threat is unpredictable (Somerville et al., 2013, 2010). The tendency to persistently monitor for threat over a long duration is likely to be closely related to trait anxiety. The impact of state anxiety may be less evident over these longer timescales. Brain regions that have consistently been linked to sustained anxiety and threat monitoring are the bed nucleus of the stria terminalis (BNST) and the insula. The BNST (also known as the ‘extended amygdala’) is located in the ventral basal forebrain (VBF) and shares many similarities with the amygdala including its composition and common projections to the brainstem and hypothalamus (Somerville et al., 2010).

Despite these similarities, it has been suggested that there is a functional dissociation between these structures, where the amygdala responds transiently to immediate threat cues, and the BNST responds to situations that require sustained monitoring for threat over a longer period of time (Somerville et al., 2010, 2013). There is also evidence to indicate that individuals with high levels of trait anxiety or spider phobia show increased activation in the VBF/BNST and insula in experimental conditions that involve monitoring for or anticipating threat (Somerville et al., 2010; Straube, Mentzel, & Miltner, 2007). These findings are consistent with theoretical frameworks proposing that anxiety is associated with hypervigilance for threat.

Figure 1 indicates that the expected patterns of facilitated and impaired attention depend on the nature of the bias (hypervigilance or selective attention) and the experimental or environmental conditions (e.g., the presence or absence of threat and the task-relevant or task-irrelevant nature of a threat). The patterns of facilitated and impaired attention that would occur in anxiety due to selective attention to threat can be understood in terms of the orienting network. Orienting involves disengaging attention from the current location, shifting to and engaging attention at a new location (Posner & Petersen, 1990). Therefore, delayed disengagement of attention from task-irrelevant threat would be one of the components of impaired attention in anxiety (e.g., Fox et al., 2001, 2002). There would also be rapid engagement with threat in anxiety (Beck & Clark, 1997; Mogg & Bradley, 1998; Williams et al., 1997) and, depending on the experimental conditions or environmental demands, this process could lead to either facilitated or impaired attention. Specifically, rapid engagement with threat would lead to facilitated attention if the threat was task-relevant or appeared in the same spatial location as a target. Impaired attention would be manifest in the case of rapid engagement with a task-irrelevant threat (i.e., attentional capture).

The proposed pattern of facilitated and impaired attention associated with selective attention to threat would only be relevant in situations where a threat was present in the environment. In contrast, the pattern of facilitated and impaired attention associated with hypervigilance would be relevant in the presence and absence of threat. In the absence of threat, hypervigilance would lead to difficulties focusing attention on an on-going task because attentional resources would be dedicated to monitoring a large region of the environment for threat (Beck et al., 2005; Eysenck et al., 2007). Similar difficulties in focusing attention on an ongoing task would occur, possibly to a greater extent, in the presence of task-irrelevant threat (Eysenck, 1992; Eysenck et al., 2007). In this situation, individuals with high levels of anxiety would detect and be unable to inhibit processing of task-irrelevant threat located anywhere within the monitored region. Facilitated attention would occur in the presence of a task-relevant threat; here, hypervigilance would allow individuals with high levels of anxiety to rapidly detect threat stimuli.

Figure 1 outlines predictions about the eye movement behaviors that would occur in the context of hypervigilance and selective attention to threat. Hypervigilance could be accomplished via two strategies: individuals with high levels of anxiety may excessively scan the environment with numerous eye movements or they might execute few eye movements (i.e., use peripheral vision) in order to maintain a broad distribution of attention (see Eysenck, 1992). Both strategies allow visual sampling of a wide region of the visual field. Rapid scanning would involve a narrow spotlight of overt attention moving across the visual field such that a large number of stimuli received short periods of foveal processing. In contrast, a broad distribution of attention would involve executing few eye movements and maintaining longer periods of visual fixation whilst covertly processing stimuli using peripheral vision. These strategies would facilitate threat detection but also lead to difficulties focusing attention on an on-going task; the latter would be demonstrated by delays in executing endogenous saccades to task-relevant neutral stimuli in both the presence (regardless of location) and absence of threat.

In contrast, selective attention to threat would be accomplished via overt visual orienting; foveal vision would be directed towards threatening stimuli such that they could be inspected in greater detail using the area of highest visual acuity. Selective attention would be evident in fast and accurate saccades towards task-relevant threat or task-relevant locations that contain threat (i.e. rapid engagement). In the case of task-irrelevant threat, selective attention might be reflected in the delayed execution of endogenous saccades away from foveal threat (i.e., delayed disengagement) or an inability to suppress exogenous saccades towards threat (i.e., attentional capture).

Based on this framework, we suggest that the results of studies measuring eye movement behavior are not readily compatible with the premise that anxiety is characterized by a pervasive selective attentional bias to threat. In particular, there is inconsistent evidence for rapid engagement or delayed disengagement of overt attention (e.g., foveal vision) from threat. Findings of rapid engagement with threat have typically been observed in free-viewing tasks or RT tasks with concurrent eye movement measures, which include simple visual displays containing two or four items (e.g., Garner et al., 2006; Mogg et al., 2007; Mogg et al., 2000; Stevens et al., 2011). These findings have not typically been replicated in studies using more complex visual displays (e.g., Derakshan & Koster, 2010; Huijding et al., 2011). Furthermore, some eye tracking evidence suggests that there is capture of overt attention by task-irrelevant threat in anxiety (Miltner et al., 2004); however, more recent studies have questioned this finding by using traditional eye tracking paradigms to show that anxious individuals are able to suppress exogenous saccades to threat stimuli (Derakshan et al., 2009; Richards et al., 2012). Findings of delayed disengagement from threatening distractors in eye tracking studies could be related to selective attention to threat (Rinck et al., 2005). However, further work demonstrates that delays in executing endogenous saccades to a target object or location are not limited to threats presented within foveal vision but also occur for threats presented in parafoveal and peripheral locations (Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Richards et al., 2012).

We propose that the results of studies measuring eye movements demonstrate a pattern of facilitated and impaired attention that is consistent with hypervigilance for threat in individuals with high levels of anxiety. Collectively, the findings suggest that executing few eye movements and maintaining a broad focus of attention allows individuals with high levels of anxiety to accumulate and efficiently detect threatening information from multiple locations (Richards et al., 2011), but also leads to increased distractibility from task-irrelevant threats presented in a variety of locations across the visual field (e.g., as indexed by delayed endogenous saccades to a target; Derakshan et al., 2009; Reinholdt-Dunne et al., 2012; Richards et al., 2012). Following Eysenck (1992), a further feature that may be relevant to the idea of excessive scanning or distractibility within a broad attentional beam is the finding of "unspecific hypervigilance" reported by Gerdes et al. (2008) and replicated by Wieser, Pauli, and Muhlberger (2009); here, anxious individuals were unable to suppress exogenous saccades to both threat and non-threat stimuli, which may reflect a tendency to monitor new visual stimuli in order to ensure that they are not threatening.

Therefore, we propose that hypervigilance is a key characteristic of attentional processing in individuals with high levels of anxiety, which is readily distinguishable from selective attention to threat. Hypervigilance for threat has been included in a number of the theoretical frameworks of anxiety and attention (e.g., Beck et al., 2005; Eysenck 1992; Eysenck et al., 2007; Rapee & Heimberg, 1997), yet it has generated very little research interest in comparison with the literature relating to selective attention to threat. Although there is some evidence consistent with the selective attention pathway (e.g. findings from free viewing paradigms and dot probe paradigms with concurrent eye movement measures), these effects seem to occur in a restricted set of experimental conditions. Therefore, we suggest that future work should aim to understand and test the parameters of hypervigilance and selective attention in anxious individuals using a variety of experimental paradigms and, as outlined in the framework, eye movement measures may provide an effective tool for characterizing these components of the attentional bias.

Clinical Implications

Research on attentional biases has, in recent years, had a direct impact on the development of novel interventions for elevated anxiety and anxiety disorder. The rationale for developing these interventions stems from findings which indicate that Cognitive Behavioral Therapy (CBT), the treatment of choice for anxiety disorders, is effective in reducing anxiety symptoms for at least 50% of those who are treated but, crucially, it is not effective for all individuals (Olatunji, Cisler, & Deacon, 2010). Therefore, there is a clear need to identify further interventions that are efficacious for individuals with an anxiety disorder and especially those who do not respond to CBT. For researchers considering attentional biases, there has been increasing impetus to translate findings of selective attention to threat in anxiety to a clinical or therapeutic setting by developing Attention Training Techniques (ATTs). ATTs aim to reduce anxiety by using experimental tasks (most frequently a modified version of the dot probe paradigm) that train individuals with high levels of anxiety to shift their attention away from threatening stimuli and towards neutral stimuli.

An example of an ATT protocol based on a modified version of the dot probe paradigm was developed by Amir and colleagues (Amir, Beard, Burns, & Bomyea, 2009; Amir, Beard, Taylor, Klumpp, Elias, & Burns, 2009). This ATT involved trials in which a threat-neutral or neutral-neutral stimulus pair was followed by a probe stimulus that the participant had to identify (an E or an F). The threat-neutral stimulus pairs were presented for the majority of the trials (66-80% of trials) and the probe always replaced the neutral stimulus, thus creating conditions that encouraged participants to direct attention away from threat. The threatening stimuli were either words (Amir, Beard, Burns et al., 2009) or disgust faces (Amir, Beard, Taylor et al., 2009). The results indicated that the ATT (vs. a placebo control condition) led to reductions in the threat-related attentional bias and reductions in self-reported and clinician-reported anxiety in individuals with GAD (Amir, Beard, Burns et al., 2009) and generalized social phobia (GSP; Amir, Beard, Taylor et al., 2009). Furthermore, a significantly higher proportion of participants no longer met diagnostic criteria for GAD or GSP following the ATT compared with the placebo control condition.

ATTs based on the dot probe paradigm are designed to target selective attention to threat; the extent to which these techniques are effective in modifying the selective attentional bias are typically assessed by comparing performance on the original (non-training) dot probe paradigm before and after the intervention period. However, the use of the dot probe paradigm as an outcome measure often obscures the extent to which reductions in the selective attentional bias following the ATT are due to changes in vigilance or changes in attention maintenance on threat. In order to distinguish between these possibilities, Amir, Beard, Taylor et al. (2009) used the spatial cueing paradigm as an outcome measure; this task involved neutral words or social threat words being used as cues (valid or invalid) to the location of a subsequent target. The results indicated that individuals in the ATT group (but not the placebo control group) were faster to disengage attention from threat following the intervention period (compared with pre-intervention). Furthermore, the ATT led to greater reductions in clinician-reported social anxiety for those individuals who showed greater improvements in the ability to disengage from threat. In contrast, there was no evidence to suggest that the ATT (vs. placebo control) led to slower engagement with threat following the intervention period (compared with pre-intervention). Thus, the ATT had a positive effect on the attention maintenance, as opposed to the vigilance, component of the selective attentional bias.

Research indicates that exposure to ATTs successfully modifies attentional biases to threat and reduces trait anxiety, state anxiety and clinical symptoms in individuals with social anxiety disorder and GAD (Bar-Haim, 2010; Cowart & Ollendick, 2010). Despite these positive findings, ATTs are not effective in all individuals with anxiety (see Bar-Haim, 2010). Furthermore, a mixed pattern of results was reported in a recent meta analysis that considered the efficacy of cognitive bias modification in reducing anxiety and depression (Hallion & Ruscio, 2011). In this meta-analysis, cognitive bias modification incorporated studies utilizing ATTs to modify the attentional bias to threat or interventions that aimed to reduce interpretation biases (i.e. reduce the tendency to interpret ambiguous stimuli as threatening). Hallion and Ruscio (2011) found that the interventions reliably led to reductions in attentional and interpretation biases; however, this effect was significantly smaller for ATTs (small effect size) compared with interventions that aimed to modify the interpretation bias. Furthermore, they found that the effect size for the reduction in anxiety following cognitive bias modification was small.

On an individual basis, the efficacy of ATTs is likely to be explained by individual differences in attention to threat prior to treatment. Bar-Haim (2010) highlighted that a selective attentional bias is not observed in all anxious individuals and research has indicated that the reductions in anxiety following an ATT are only observed in individuals who show a selective attentional bias to threat prior to treatment (Amir, Taylor, & Donoghue, 2011).

Our proposal that hypervigilance is a key component of attentional processing raises the possibility of developing and improving the efficacy of ATTs. Existing ATTs aim to modify selective attentional processes, but they are not designed to modify any atypical attentional processes that occur prior to or during threat detection (e.g., hypervigilance and attentional broadening). There may be benefits associated with ATTs that promote focused attention and reduce the tendency to monitor for threats across a broad region of the visual field, thus minimizing interference from task-irrelevant threats and gradually reducing the sensitivity of the threat detection mechanism. Rather than specifically training individuals to direct attention away from threatening stimuli, this training would be designed to improve attentional focusing on relevant stimuli and on-going tasks in both the presence and absence of threat.

The training program developed by Bomyea and Amir (2011) is an example of a protocol that may be useful in reducing hypervigilance for threat in anxious individuals. Bomyea and Amir (2011) aimed to reduce the frequency of thought intrusions in young adults by training inhibitory control; this training involved a working memory task which either required high inhibitory control (experimental group) or low inhibitory control (control group). Following training, the participants completed a thought suppression task in which they were asked to recollect a negative personal memory and then, over a short period (15 minutes), they were asked to indicate every time they experienced a thought related to that memory. The results indicated that the high inhibitory control group experienced significantly fewer thought intrusions compared with the low inhibitory control group; that is, the inhibitory control training was associated with a greater ability to inhibit intrusive thoughts. Although this study was conducted with healthy adults, Bomyea and Amir (2011) highlighted that a difficulty inhibiting intrusive thoughts is a common feature of anxiety and depression. Furthermore, they highlighted the potential utility of this type of domain-general inhibitory control training in addressing the impairments in executive functioning and attentional control that occur in individuals with anxiety and depression. This paper fits within a broader set of studies that have considered the impact of improving attentional control via working memory training, where preliminary findings have highlighted positive change on attentional control and decreases in self-report anxiety symptoms (e.g., Roughan & Hadwin, 2011).

Extending this research, we suggest that domain-general attentional control training may also be effective in reducing hypervigilance for threat in individuals with elevated anxiety. This training could be used to promote focused attention, suppress the tendency to monitor the environment for threatening stimuli and reduce interference from task-irrelevant threat. Therefore, we suggest that the efficacy of ATTs could be enhanced by implementing a more comprehensive intervention protocol, which applies different attention modification techniques (e.g. threat bias training or domain-general attentional control training) to the components of attentional processing that occur under different environmental conditions. By developing a range of ATTs it also becomes possible to assess attentional biases prior to treatment (e.g., to establish whether an individual shows hypervigilance, selective attention or both) and to tailor the treatment protocol on an individual basis such that it targets the appropriate components of attentional processing.

Conclusions

To conclude, recent studies using eye movement methodology are consistent with the proposal that anxious individuals show hypervigilance for threat via a broad focus of attention, where this process leads to facilitated threat detection, increased distractibility and fewer eye movements being executed in the presence of threat. It remains possible that selective attention to threat, and its associated patterns of facilitated and impaired attention, also occurs in anxiety as a separate attentional process; although evidence from eye movement research does not consistently support this proposition. Empirical evidence from studies using eye movement measurements most clearly support theoretical frameworks where anxiety is characterized by hypervigilance and enhanced threat detection (Eysenck, 1992) and impaired attentional control (Eysenck et al., 2007).

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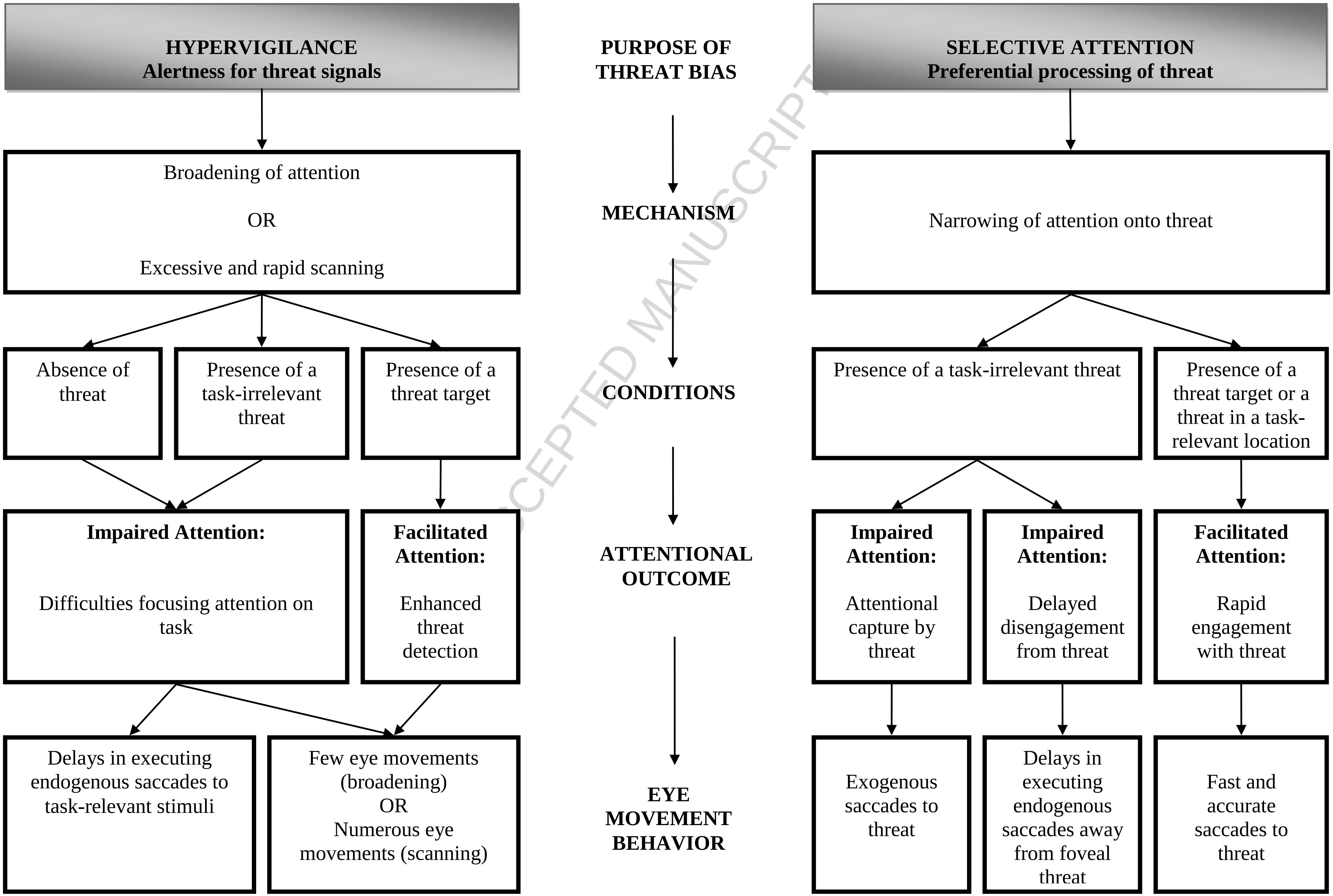
Figure 1: A conceptual framework for understanding attentional pathways for individuals with high levels of trait anxiety that operate differentially across experimental conditions and that reflect eye movement behavior indicating (1) selective attention to threat (right hand pathway) and (2) hypervigilance for threat (left hand pathway).


HYPERVIGILANCE
Alertness for threat signals
PURPOSE OF THREAT BIAS
SELECTIVE ATTENTION
Preferential processing of threat
Broadening of attention
OR
Excessive and rapid scanning
MECHANISM
Narrowing of attention onto threat
Absence of threat
Presence of a task-irrelevant threat
Presence of a threat target
CONDITIONS
Presence of a task-irrelevant threat
Presence of a threat target or a threat in a task-relevant location
Impaired Attention:
Difficulties focusing attention on task
Facilitated Attention:
Enhanced threat detection
ATTENTIONAL OUTCOME
Impaired Attention:
Attentional capture by threat
Impaired Attention:
Delayed disengagement from threat
Facilitated Attention:
Rapid engagement with threat
Delays in executing endogenous saccades to task-relevant stimuli
Few eye movements (broadening)
OR
Numerous eye movements (scanning)
EYE MOVEMENT BEHAVIOR
Exogenous saccades to threat
Delays in executing endogenous saccades away from foveal threat
Fast and accurate saccades to threat

Highlights

- We highlight selective attention and hypervigilance as distinct biases in anxiety.
- We present a novel framework for understanding eye movement behavior in anxiety.
- We outline the application of this framework to clinical intervention.