Theories and measurement of visual attentional processing in anxiety

Mariann R. Weierich and Teresa A. Treat

Yale University, New Haven, CT, USA

Andrew Hollingworth

University of Iowa, Iowa City, IA, USA

Most theoretical models of anxiety disorders implicate maladaptive visuo-spatial attentional processing of threat-relevant information in the onset and maintenance of symptoms. We discuss the central mechanistic hypotheses in clinical science regarding problematic attentional processing of threat in anxiety, reconcile what appear to be contradictory predictions, and integrate those hypotheses to describe comprehensively the overt and covert mechanisms of attentional processing within discrete perceptual episodes. In so doing, we examine critically the prevailing theoretical assumptions and measurement models underlying the current investigations of attention and anxiety, and we advocate for increased precision in the translation of models from vision science to the examination of the mechanisms of attentional processing in anxiety. Finally, we discuss the implications of this approach for future translational research that examines the role of attention in anxiety and its treatment.

Most theoretical models of anxiety implicate attention to threat-relevant information in the aetiology and maintenance of disorder (e.g., MacLeod & Mathews, 1988; Mathews & MacLeod, 1994; Mogg & Bradley, 2003). Individuals with anxiety disorders generally are thought to process threat-relevant information preferentially, and the role of such maladaptive attentional processing as a potentially causal or maintaining factor for symptoms has become the focus of a large body of research (e.g., Fox, Russo, Bowles, & Dutton, 2001; Mineka & Öhman, 2002; Mogg & Bradley, 1998). Researchers have attempted to discover the mechanisms underlying the differences in attentional processing between anxious and

Correspondence should be addressed to: Mariann R. Weierich, Massachusetts General Hospital – East MGH Psychiatric Neuroimaging Research Program, Building 149 13th Street Room 2681, Charlestown, MA, 02129, USA.
E-mail: weierich@nmr.mgh.harvard.edu

non-anxious individuals—is the attention of individuals with anxiety disorders characterised by initial facilitation toward threat and later avoidance of threat (e.g., Mogg & Bradley, 1998), or by maintained attention to threat (Fox et al., 2001)? In addition, what changes in attentional processing might we expect to see during or following traditional cognitive-behavioural treatment or treatment that targets attentional processing directly? Most work that addresses the role of attention in anxiety has focused on visual attention, as fear-relevant cues in the world often are visual, and we will confine our discussion to this modality.

The aim of the present paper is neither to review exhaustively the literature in attention and anxiety, nor to provide a listing of the most commonly employed experimental methods, which has been accomplished comprehensively elsewhere (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Yiend & Mathews, 2005). Rather, our intent is to examine critically the theoretical assumptions and measurement models underlying the current investigations of the role of attention in anxiety, and to advocate for increased precision in the examination of the attentional mechanisms in anxiety from a vision science perspective. To that end, we discuss the two dominant hypotheses in clinical science regarding the mechanisms of maladaptive attentional processing of visual threat stimuli in anxiety, evaluate the most commonly used measurement approaches for each, and integrate the two into a more comprehensive working model of attentional processing within a single perceptual episode. To enhance conceptual clarity in our arguments related to the mechanisms of visual processing, we also outline the principal properties and functions of attention as conceptualised by vision scientists. Finally, we discuss the implications of the integrated conceptual and measurement approaches for the examination of the role of visual attention in anxiety and its treatment.

THE HYPOTHESISED ROLE OF ATTENTIONAL PROCESSING IN ANXIETY

Two central hypotheses, the vigilance–avoidance (VA) hypothesis and the attention maintenance (AM) hypothesis,[1] have been proposed to explain the interaction of visuo-spatial attentional processing and anxiety (e.g., Mogg & Bradley, 1998; Fox et al., 2001). Both hypotheses attempt to account for the

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[1] Fox and colleagues (e.g., Fox, Russo, Bowles, & Dutton, 2001) generally refer to the hypothesis they advance as the "delayed disengagement" hypothesis. We use "Attention Maintenance" to reflect delayed disengagement as well as the associated mechanism of interest; the mechanism preventing attentional disengagement is the continued maintenance of attention to the threatening stimulus.

extent to which anxious individuals initially attend more efficiently to threat-relevant information, as well as the extent to which such individuals are more or less efficient in moving attention away from threat-relevant information. These hypotheses have been supported by two essentially independent lines of research, and, at first glance, they appear to make contradictory predictions regarding the mechanisms of attentional processing in anxiety. The VA hypothesis proposes that attention is initially directed more efficiently to threat, but that this initial period of threat vigilance is followed by later avoidance of threat. The AM hypothesis posits that attention is not directed more efficiently to threat, but that once attended, threatening stimuli tend to hold attention, making the disengagement of attention from threatening stimuli difficult.

We review these hypotheses and suggest that, when approached from the perspective of vision science, they are not incompatible. Our analysis depends upon the assumption that attention is composed of multiple component mechanisms that serve functionally distinct purposes and are implemented by distinct cognitive operations. Thus, the apparent contradiction between the AM and VA hypotheses reflects the degree to which they address two different sets of attentional mechanisms. We further suggest an integration of the hypotheses that provides a more comprehensive framework for the mechanisms of visual attentional processing of threat within single perceptual episodes.

The VA and AM hypotheses also provide a broad conceptual umbrella for the measurement paradigms and methods that commonly are used to examine the role of attentional processing in anxiety. We suggest that three fundamental features of the measurement approaches associated with the VA and AM hypotheses highlight the degree to which the hypotheses are complementary. That is, paradigmatic differences in (1) the overt versus covert processing of stimuli, (2) the timescale of processing, and (3) the presence or absence of stimulus competition provide the means for the reconciliation of the two hypotheses.

Before further discussion of the theory and measurement pertaining to the role of attention in anxiety, as well as our rationale for the integration of prior predictions, it is necessary to understand the concept of attention as developed in the literature on visual perception. As noted earlier, the erroneous assumption that all "attention" refers to the same mechanism fosters a significant degree of confusion in the understanding of the relevant hypotheses and the comparison of findings about attention across studies. Thus, we next review the basic literature on attention, with particular emphasis on the subcomponent mechanisms. We acknowledge that many of our readers already are well-versed in the fundamentals of visual perception and attention, and we suggest that such individuals might choose to proceed

more rapidly to the specific discussion of theory and measurement of attention in anxiety.

FUNDAMENTALS OF ATTENTION

An attentional process is any cognitive operation that results in the selection of some information over other information. For example, when searching for a friend at a train station, you might selectively attend to the subset of people who are arriving on the correct train, shifting attention from one passenger to the next in an attempt to find your friend. Your friend is tall, so when categorising each passenger, you preferentially attend to height. Your friend, standing nearby, calls your name, and your attention then shifts to the source of the auditory signal. Upon recognising your friend, you selectively recall memories of the friendship. Finally, you consider a handshake or a hug; the latter response is selected over the former.

As is clear from this example, selective attention is critical for intelligent behaviour within the complex tasks and environments that comprise much of waking life. Almost any action requires selection of some sort, because the world is full of objects, agents, and potential actions that compete for processing priority. Roles for selective attention have been proposed in vision, audition, categorisation, memory, response selection, and motor control (see Pashler, 1998). When applied to clinical experimental psychology, attention all too often is treated as a coherent, unitary cognitive construct, rather than as a collection of cognitive mechanisms that serve a similar function: selection. For example, the Stroop paradigm often is used in clinical psychology as a global measure of "attention" in psychopathology (Williams, Mathews, & MacLeod, 1996). However, the Stroop paradigm primarily reflects response selection and does not necessarily generalise to other mechanisms of attention (e.g., Baldo, Shimamura, & Prinzmetal, 1998). A preferred approach is to isolate specific mechanisms of attention within a particular domain and study the interaction between these mechanisms and psychopathology.

In the course of isolating particular mechanisms of attention for study, it is important to understand how attention researchers have "carved attention at the joints". Below, we discuss important functional and system-level distinctions that should guide the study of visual attention in psychopathology.

Mechanisms of attention in visual perception

Overt attention: Eye movements.   Vision is inherently selective, because the human retina does not have uniform sensitivity across the visual field. High-resolution visual processing is limited to a small, central region of the

retina (the fovea) that covers only about 2° of visual angle. To obtain high-resolution information from individual objects, the eyes are shifted to bring those regions onto the fovea. Typically, this is accomplished by rapid eye rotations called *saccades*. The eyes make approximately three saccades each second (Henderson & Hollingworth, 1998; Rayner, 1998), resulting in hundreds of thousands of eye movements each day. Periods of relative stability between saccades are termed *fixations*, each lasting approximately 300 ms on average (Henderson & Hollingworth, 1998). During these stable fixations, visual information is encoded, and we see.

Eye movements enable the acquisition of high-resolution visual information, but this is not their only function. Intelligent behaviour requires the ability to specify objects in the world and keep track of them. If a person sees three dogs and knows that one is vicious, gaze can be used to mark the threatening dog (by maintaining fixation on it). This pointing function is used to support everyday activities, with gaze position tightly linked to current motor actions (Hayhoe, 2000; Land, Mennie, & Rusted, 1999). For example, while making tea, individuals fixate the handle of a teapot to guide reaching and the teacup itself to monitor the level of the liquid. Thus, gaze fixation specifies objects as the targets of action, connecting visual perceptual information with internal motor programmes and other cognitive operations (Ballard, Hayhoe, Pook, & Rao, 1997).[2]

Eye movements are the principal means by which goal-relevant objects are selected for further perceptual processing, recognition, and action. By monitoring the position, duration, and sequence of eye fixations on a stimulus, researchers can determine which regions (and thus what information) attracted attention, held attention, or were avoided. The sequence of eye movements unfolds over the time course of multiple seconds of viewing, providing a continuous window on the perceptual operations supporting behaviour.

Covert attention.   Although humans attend by moving the eyes to fixate objects, attention also can operate in vision without eye movements. This mechanism is termed *covert visual attention* (as opposed to *overt* eye movements).[3] During a fixation, the visual system can select a particular region of the visual field for more extensive processing. Posner demonstrated the ability to attend covertly in a series of cueing studies (Posner, Snyder, & Davidson, 1980). With the eyes kept still, participants were cued to a particular region of space where a simple target (e.g., a dot) was likely to appear. Detection of the target was faster at the cued location, demonstrating

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[2] Covert attention can also be used to mark objects and keep track of them (Pylyshyn, 2000).

[3] It is covert attention to which visual scientists typically (but not always) refer when they use the term "visual attention".

facilitated perceptual processing at the attended region. Posner conceptua- lised covert attention as a "spotlight" that can be oriented to different regions of the visual field. Although the spotlight metaphor has required modification (e.g., Eriksen & St. James, 1986; LaBerge & Brown, 1989), the basic conceptualisation of covert attention as an internal mechanism that can be oriented to increase visual sensitivity has remained intact.

Posner further decomposed covert attention into three principal sub- component operations: shift, engage, and disengage. In this view, to transfer attention to a new location, attention must first be *disengaged* from the current location, then *shifted* and *engaged* at the new location. The shift and engage components both concern the orienting of attention to a new object or location, and it is unclear whether these reflect distinct cognitive operations. Thus, we use the terms "orienting" or "shifting" attention to refer to the entire process of directing attention to a new object or location. Whereas patterns of eye movements typically unfold over multiple seconds of viewing, covert attentional shifts can operate on a much faster timescale, with shifts of attention sometimes requiring only 50–100 ms (e.g., Müller & Rabbit, 1989).

The consequences of attending covertly to a particular object or location are multifaceted. First, as discussed above, attention enhances early visual processing to increase perceptual sensitivity (Hillyard, Vogel, & Luck, 1998; Pestilli & Carrasco, 2005). Second, covert attention enables the binding of different perceptual features (e.g., colour and shape) into a representation of a complete object (Treisman & Gelade, 1980). Third, attention directly influences visual awareness; participants' ability to perceive and report unattended visual stimuli is quite limited (Mack & Rock, 1998; Raymond, Shapiro, & Arnell, 1992). Fourth, covert attention is critical for the transfer of perceptual information into memory. Visual attention controls which objects gain access to visual short-term memory (Hollingworth & Henderson, 2002; Schmidt, Vogel, Woodman, & Luck, 2002), and thus knowing where a participant attended allows one to predict what is remembered. Finally, covert attention selects the target of the next eye movement. Before a saccade, attention is shifted covertly to the saccade target object (Hoffman & Subramaniam, 1995). Thus, covert attention and eye movements are distinct, yet functionally coupled; although covert shifts can occur without eye movements, eye movements are always preceded by a covert shift of attention (Klein, 1980).

Control of attentional allocation

The effects of attention on perception and memory are substantial. Individual differences in where and when attention is directed to visual stimuli will largely determine differences in what people perceive, remember, and act upon. To

understand how abnormal attentional processing might cause or maintain symptoms of psychopathology, one must understand the basic factors that control where attention is directed. The allocation of covert attention and the overt movement of the eyes are both controlled by an interaction between top-down, goal-directed mechanisms and low-level, stimulus-driven mechanisms (e.g., Desimone & Duncan, 1995). In individuals with anxiety, for example, the balance between the top-down tendency to select threat-relevant information and the bottom-up, low-level features of threat-relevant stimuli may be disrupted, such that control over the allocation of attention is diminished, even in the face of task demands (Eysenck & Calvo, 1992; Eysenck, Derakhshan, Santos, & Calvo, 2007).

A fundamental problem for the visual system is to decide which locations or objects deserve priority. Often, priority is goal dependent. For example, a golfer might preferentially attend to white objects when searching for a lost ball. In addition, we generally can exert control over where the eyes are directed (e.g., averting gaze from an angry face) and where covert attention is directed (e.g., monitoring someone out of the corner of one's eye). Moreover, real-world knowledge can control the allocation of attention; when searching for an object in a scene, individuals rapidly direct attention to locations known to contain that type of object (Torralba, Oliva, Castelhano, & Henderson, 2006). Given that we have considerable control over where we attend, monitoring where a participant attends provides direct evidence about individual differences in the priority given to particular objects and agents. For example, a top-down bias to avoid threatening objects can be observed directly by monitoring eye movements (e.g., Calvo & Avero, 2005; Pflugshaupt et al., 2005).

Although top-down goals and knowledge help determine the focus of attention, some visual events attract attention regardless of task; they capture attention (Yantis & Jonides, 1984). Sudden changes in the world (e.g., when an object looms toward a viewer; Franconeri & Simons, 2003) are given high priority regardless of top-down goals. Current evidence suggests that a fairly small set of perceptual events, including the abrupt appearance of an object and object motion (Franconeri & Simons, 2003; Yantis & Jonides, 1984), capture visual attention and the eyes. Such capture is likely to be based on low-level sensory events that signal abrupt change (Franconeri, Hollingworth, & Simons, 2005). However, it is possible that object meaning, including anxiety-relevance, might influence attention capture, and there is currently considerable debate over possible stimulus-driven attention capture by anxiety-inducing stimuli (Cave & Batty, 2006; Öhman, Flykt, & Esteves, 2001).

Based on the presented framework for the operation of visual attention, we now turn to a more detailed discussion and reconciliation of the central mechanistic hypotheses of visual attentional processing in anxiety.

RECONCILIATION OF THE VA AND AM HYPOTHESES

As noted earlier, the VA hypothesis (Mogg & Bradley, 1998; Mogg, Bradley, Miles, & Dixon, 2004) proposes that anxious persons (a) initially attend to threat-relevant information, which facilitates rapid responding to perceived threat but also heightens anxiety; and (b) subsequently avoid threat-relevant information, which minimises the negative affect provoked by the fear-relevant information, but also precludes adaptive habituation to and objective reappraisal of anxiety-provoking stimuli. This pattern corresponds to enhanced perceptual discrimination of a spider among other stimuli on a windowsill, for example, followed by strategic avoidance of perceptual engagement with that spider. Note that avoidance of direct perceptual engagement via eye movements does not imply that the individual no longer is processing the presence of threat; as discussed earlier, it is possible to continue to monitor and track threat-relevant stimuli covertly, even when the eyes are fixated elsewhere.

In apparent contrast to the VA hypothesis, the AM hypothesis proposes that clinically anxious persons do not orient more rapidly to anxiety-inducing stimuli, but rather have their attention maintained by threat-relevant stimuli, such that they disengage from them more slowly (Derryberry & Reed, 2002; Fox et al., 2000, 2001; Yiend & Mathews, 2001). The latter aspect of the AM hypothesis could maintain and exacerbate anxiety by maintaining longer perceptual processing and explicit awareness of threatening information, which may be early, low-level precursors of a ruminative and perseverative focus on threat-relevant information.

When considered from the framework of vision science outlined previously, the VA and AM hypotheses are not incompatible. First, although they appear to make different claims about the speed of the initial allocation of attention to threatening stimuli, the experimental paradigms most commonly used to inform the two hypotheses actually test different components of the allocation of attention to threat. In general, paradigms that provide the most support for vigilance introduce a competition among multiple stimuli for selection (see Desimone & Duncan, 1995), and vigilance likely reflects a bias toward selection of threat-relevant stimuli as targets of attention in the presence of stimulus competition. This is consistent with the clinical phenomenon of overt scanning of the environment for threat-relevant information in anxious individuals. In contrast, covert attentional paradigms, in which a single stimulus is abruptly displayed, isolate and measure the speed of the covert shift of attention to a single, salient object. Thus, the two views are compatible if we assume that threat-relevant stimuli are more likely to be selected as targets of attention (VA), but that the speed of the covert shift of attention to a stimulus is not influenced by threat-relevance (AM).

Second, the seemingly incompatible claims regarding attentional processing after an object has been attended can be reconciled by considering the underlying mechanisms proposed by each hypothesis. It is perfectly possible that on the time scale of rapid, covert shifts of attention, attention indeed is maintained on threat-relevant stimuli (AM), but that on the longer time scale of overt eye movements and behaviour, participants show an avoidance pattern later in viewing (VA; e.g., Calvo & Avero, 2005; Pflugshaupt et al., 2005).

Figure 1 illustrates our suggested integration of the VA and AM hypotheses. The figure depicts perceptual processing over multiple seconds of viewing as covert attention and the eyes are directed to a series of objects within a complex, natural environment. Circles represent individual objects selected and fixated within the scene. Overt vigilance for threat among all visible stimuli operates early during viewing and reflects the top-down prioritisation of threat-relevant stimuli. During this period, therefore, threat stimuli are more likely to be selected as targets of attention. Later in viewing, however, overt avoidance of threat stimuli manifests as a relatively low probability that threat stimuli will be selected as the targets of attention and the eyes. Thus, the pattern of vigilance followed by avoidance is viewed as a change in top-down priority for the selection of threat-relevant objects as viewing unfolds over multiple seconds within an environment in which multiple stimuli compete for attentional prioritisation.

With the VA hypothesis explaining the large-scale pattern of object selection within a scene, the AM hypothesis can be applied to the smaller-scale, covert attention events involved in shifting attention to and away from individual objects. Although attention is more likely to be directed to threat objects early in viewing (VA), the speed of the covert shift itself need not vary for threatening and non-threatening stimuli, as illustrated in Figure 1. Once attention has been directed to an object, however, attention dwells longer on threat stimuli and is more difficult to disengage from threat stimuli.[4] Such local disengage effects can occur largely independently of top-down prioritisation over longer time scales. Thus, differing claims about attentional processing before and after a threat object has been attended can be reconciled if differences in covert maintenance on an individual object (AM) are embedded within a larger pattern of early vigilance and later avoidance (VA).

Consider the following example. Upon entering a room, an individual with social phobia might be vigilant for the presence of threatening faces, exhibiting a top-down bias to select unfriendly faces or features of such faces (e.g., frowns) as targets of attention from among other competing

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[4] Given the close relationship between covert attention and eye movements, longer attentional dwell times on threat objects should produce longer fixation durations on those objects.

Vigilance/ Avoidance

Early in viewing, Overt Vigilance for threat. High probability that threatening stimuli will be fixated.

Late in viewing, Overt Avoidance of threat. Low probability that threatening stimuli will be fixated.

Sequence of Objects Selected and Fixated →

NT T T NT T T .... NT NT NT T NT NT

Attention Maintenance

Covert Orienting to object (efficiency of shift not influenced by threat status)

Overt Shift (saccade) to object

Covert Disengagement from object (disengagement delayed for threatening stimuli)
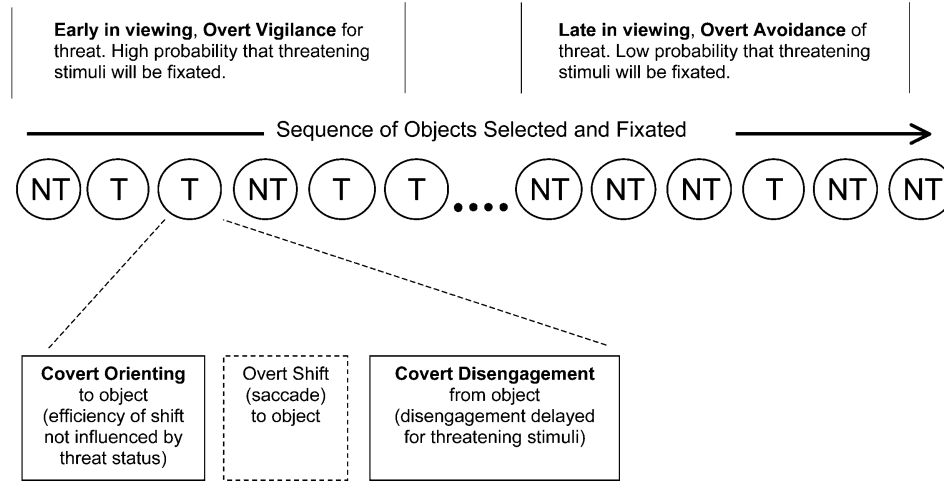
Figure 1.   Synthesis of the VA and AM hypotheses within a single perceptual episode. *Note*: NT = Non-Threat stimulus; T = Threat-relevant stimulus.

objects, and scanning regions of the room likely to contain unfriendly faces with overt shifts of the eyes (VA). However, when attention is shifted to an unfriendly face, the speed of the rapid covert shift of attention is not influenced by the threat-relevance of the object (AM). Once the threatening face is attended, the social phobic's attention dwells longer on the threatening face, and the phobic individual has difficulty disengaging covert attention from the face (AM). However, once attention *is* successfully disengaged from the face, the social phobic avoids that face (and other threatening faces), perhaps by moving the eyes away from the person, by inhibiting the return of gaze to the location of the person,[5] or by leaving the room (VA).

Next, we discuss the experimental approaches and results relevant for understanding the main components of the two hypotheses: vigilance, avoidance, covert orienting, and covert disengagement. We argue that the existing data support both hypotheses and that the empirical literature tells a consistent and coherent story when considered from the perspective of our integrated approach.

Vigilance.   The vigilance component of the VA hypothesis consistently has been observed on a relatively long timescale (e.g., > 500 ms) when multiple stimuli compete for attention,[6] as in the usual design of the *dot-probe paradigm* (e.g., Bradley, Mogg, Falla, & Hamilton, 1998; Mogg,

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[5] In the discussed studies (e.g., Calvo & Avero, 2005; Pflugshaupt et al., 2005), inhibition of overt return of gaze to threat (e.g., spider) occurs. Inhibition of covert return of attention to a cued location is also relevant to the current discussion; such inhibition, or IOR, refers to the tendency of the visual system to inhibit return of covert attention to locations (e.g., Posner & Cohen, 1984) or objects (e.g., Tipper, Driver, & Weaver, 1991) that recently have been attended. IOR is evolutionarily adaptive; within a short timeframe, inhibiting attention to a location or object tagged as non-threatening allows more efficient processing of other locations or objects. Interruption of IOR has been shown to occur in response to threat-relevant stimuli in anxious individuals (e.g., Fox, Russo, & Dutton, 2002).

[6] Although researchers have not mapped emotional Stroop task interference onto the VA or AM hypotheses, the Stroop interference effect has been interpreted variously as the maintenance of attention to word meaning or vigilance for threat-relevant word meaning (e.g., Williams, Mathews, & MacLeod, 1996). We agree with recent arguments that the task adequately measures neither, and is primarily of interest only as evidence of more general differential processing of threat in anxiety (Algom, Chajut, & Lev, 2004). Clear interpretation of Stroop results with respect to the subcomponents of attentional processing is limited. The target and distractor stimuli are superimposed in this task, as target colour and distractor word are properties of the same stimulus. From the AM perspective, therefore, it is not possible to determine whether the interference effect reflects facilitated orienting to threat words or difficulty disengaging from them (Fox et al., 2001). In addition, target tasks and threat-relevant stimuli generally are not superimposed spatially in the real world; therefore, this characteristic of the Stroop task limits its generality and its degree of relevance to the research questions of interest (i.e., where attention is allocated in the world), including the examination of vigilance and avoidance as posited by the VA hypothesis.

Bradley, deBono, & Painter, 1997). The dot-probe, or attentional-probe, task often is used to measure attentional processing, in particular vigilance, in anxiety (e.g., MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 2003). Participants view two stimuli, such as one neutral and one threat-relevant word, presented above and below, or to the left and right of, fixation, typically for 500 ms. Stimuli then offset, and a probe (e.g., a dot) appears in the location of one of the stimuli. Participants respond by indicating the location of the probe. If a participant has been attending to the threat-relevant stimulus, the response time for indicating the probe location in the threat position should be faster than the response time for the probe in the neutral stimulus location. It follows that faster response times to probes presented in the threat location are interpreted as vigilance for threat. Faster response times to probes in the same position as anxiety-relevant stimuli have been found in generalised anxiety disorder (GAD; e.g., Bradley, Mogg, Millar, & White, 1995), social anxiety (e.g., Mansell, Clark, Ehlers, & Chen, 1999; Musa, Lepine, Clark, Mansell, & Ehlers, 2003; Pineles & Mineka, 2005; Pishyar, Harris, & Menzies, 2004), panic disorder (e.g., Kroeze & van den Hout, 2000), and posttraumatic stress disorder (PTSD; e.g., Bryant & Harvey, 1997). These results have been described variously as evidence for preferential "orienting" of attention to threat, or as vigilance for threat. In general, dot-probe results appear to support vigilance toward anxiety-relevant stimuli in anxious individuals on a longer timescale (i.e., > 500 ms), although we suggest that two characteristics of the task preclude clear interpretation of results.

One difficulty with interpretation of dot-probe results is specific to the detection of a dot onset as the target task. Reaction time in simple onset detection paradigms can be strongly influenced by response bias (see Luck & Vecera, 2002), in which participants' informational criterion for target response differs among stimulus conditions. A useful modification of the task requires participants to perform perceptual discrimination as the target task (e.g., Mogg & Bradley, 1999); for example, the target might be one of two symbols (e.g., "%" and "&"), and participants must identify the symbol. In addition, a perceptually difficult task (i.e., distinguish between "%" and "&", rather than "X" and "O") is more likely to require a shift of attention, and therefore is best to detect attentional allocation. This modification allows the researcher to better detect the presence of response bias. If participants set a low informational criterion for response in a particular stimulus condition, this will be observable as faster RTs but will also produce lower accuracy, a speed–accuracy trade-off. If accuracy across conditions is similar (no speed–accuracy trade-off), one can be fairly confident that differences in RT reflect true differences in the efficiency of perceptual processes, rather than bias.

Although the addition of a discrimination task enhances the interpreta-
tion of results, two major limitations to interpretation of dot-probe data as
evidence of initial allocation of attention remain. First, as noted by several
researchers, the commonly used 500 ms duration of the stimulus pair
presentation is relatively long (Bradley, Mogg, & Millar, 2000; Cooper &
Langton, 2006; Fox et al., 2001). It is certainly possible to attend to one
location and shift to the other, with or without eye movements, within a
500 ms window. Therefore, one cannot determine whether longer response
times to probes in the non-threat location reflect a greater probability of
initially shifting attention to threat-relevant stimuli (i.e., orienting) or
difficulty withdrawing attention from threat-relevant stimuli (i.e., attention
maintenance).

A second concern about the dot-probe paradigm is the lack of overlap
between this method and vigilance as it is likely to manifest in real-world
situations. Anxious individuals rarely view only two potential targets of
attention, and vigilance presumably occurs over much longer timescales. For
example, scanning a room for the presence of spiders likely will span
multiple seconds of viewing and require directing covert visual attention and
the eyes to multiple objects sequentially within a complex scene (see Figure
1). Thus, although vigilance may be observed within the dot-probe
paradigm, the mechanism necessarily is compressed given the constraint
of only two possible targets for selection. Vigilance may be better studied in
experimental paradigms that afford sequential attention to multiple objects
and that involve perceptual processes optimised for finding and identifying
threat-relevant objects.

An attention paradigm that meets these requirements quite well is the
visual search task. In visual search, participants view an array of objects
within which is embedded a target object. How rapidly the target is found
reflects the efficiency with which attention was directed to the target.
Vigilance is observed in the more rapid detection of anxiety-relevant targets
compared to other targets (e.g., Fox et al., 2000; Öhman et al., 2001). In
anxiety-relevant designs, participants view stimulus arrays containing threat
and non-threat stimuli. Generally, fear-relevant stimuli are targets in fear-
irrelevant matrices and vice versa, although stimulus configurations vary.
Participants indicate their detection of a discrepant target. In the original
visual search literature, response times in general increase in a linear fashion
as a function of the number of search items (set size; Treisman & Gelade,
1980). The slope of this linear function can provide a rough estimate of the
nature of stimulus processing; flatter slopes (e.g., average ~ 5 ms RT per
item) are thought to reflect the processing of presented stimuli in parallel,
such that the discrepant target "pops out" of the stimulus array (Treisman &
Gelade, 1980). Parallel search is often observed when the search task
involves a single perceptual feature, as in a search for a green stimulus

among red stimuli. Steeper slopes (e.g., average ~ 50 ms RT per item) are thought to reflect serial processing of the stimuli, such that each available stimulus is processed in succession until the target is located. Such slopes are more often observed in conjunctive searches, or searches wherein the target must be identified via multiple features, of which one or more is shared with distractors. Translated to the study of anxiety, these properties of the visual search task are thought to represent the degree to which anxiety-relevant stimuli ''pop out'' of an array for preferential, and perhaps pre-attentive, processing by anxious individuals.

Several visual search studies have found that animal phobic participants were more vigilant for fear-relevant picture targets than controls (Lipp, Derakhshan, Waters, & Logies, 2004; Öhman et al., 2001), and that socially anxious participants detected discrepant angry faces among neutral faces more rapidly (Gilboa-Schechtman, Foa, & Amir, 1999). Although the number of studies is limited, these results provide preliminary support for the notion of vigilance as conceptualised within the VA hypothesis; anxious individuals sometimes attend preferentially to threat-relevant information when it is presented in a stimulus array.

On the other hand, in several other studies, participants with social phobia did not reveal speeded processing of anxiety-relevant words (Rinck & Becker, 2005; Rinck, Becker, Kellermann, & Roth, 2003) or angry face stimuli (Juth, Lundqvist, Karlsson, & Öhman, 2005). Instead, participants in several of these studies showed longer RTs when anxiety-relevant stimuli were distractors within the array (Rinck & Becker, 2005; Rinck et al., 2003), which could implicate vigilance for those distractors or difficulty with disengagement from them.

Visual search paradigm variants (i.e., presentations of stimulus arrays that range from grid patterns to complex scenes in which participants must detect target stimuli) used together with eye-tracking technology are of particular use for addressing questions relating to the degree to which anxious individuals overtly prioritise threat-relevant information in the presence of multiple stimuli. Some of the strongest evidence for such differential processing in anxiety comes from recent eye-tracking work, in which attentional allocation was observed continually over multiple seconds of viewing. Contrary to prior visual search findings of vigilance (e.g., Öhman et al., 2001), the results of two studies incorporating eye-movement measurement with visual search did not support more efficient detection of single fear-relevant targets. Rather, consistent with prior evidence of differential processing of threat-relevant distractors, the results indicated that attentional capture was observed only when a fear-relevant stimulus served as a distractor. Under these conditions, the eyes appeared to be drawn to the threat-relevant distractors, and reaction time performance was impaired in spider phobics (Miltner, Krieschel, Hecht, Trippe, & Weiss,

2004). The authors interpreted the findings as interference caused by competition between the strategic attentional set of the participants and attentional capture by the threat-relevant stimuli. Similarly, results of another set of visual search studies did not show evidence of enhanced attentional allocation to threat-relevant targets in spider phobics during a discrepant target search, although speeded detection of threat-relevant targets was observed in task variants for which attentional set was enhanced, such as when participants were provided with the name of the animal to be detected (Rinck, Reinecke, Ellwart, Heuer, & Becker, 2005)

Viewing behaviour during the presentation of complex scenes is also relevant, as anxious individuals infrequently encounter decontextualised threat-relevant stimuli in the world, and the impetus for all the work examining attentional processing is the goal of understanding how such individuals behave differentially in the larger environment. One study utilised this approach to evaluation of the VA hypothesis by combining eye-tracking with the presentation of varying numbers of anxiety-relevant stimuli (i.e., spiders) within everyday scenes (e.g., bathroom), and instructing participants to indicate the number of stimuli present (Pflugshaupt et al., 2005). Within scenes, the researchers found evidence for overt vigilance for threat; compared to controls, spider-fearful participants showed faster initial fixations on spider stimuli, and subsequent earlier fixations closer to spider stimuli (Pflugshaupt et al., 2005). Note that the fastest time to initial fixation within this experiment averaged just under 1000 ms; this clearly reflects the timescale of overt, rather than covert allocation of attention.

The use of eye-tracking methodology for the examination of visual attentional processing in anxiety is relatively new, and variation in study designs makes it difficult to draw conclusions regarding apparently conflicting results regarding vigilance. For example, Pflugshaupt et al. (2005) used time to initial fixation as a measure of vigilance, which is more precise than inferring vigilance from overall RT to target, as in prior search studies. In addition, the search task in that study utilised more naturalistic scenes than the traditional grids; locations of spider stimuli were more consistent with their context, and perhaps therefore more easily detected. These and other design variations across studies should be considered when comparing results.

Avoidance.   The avoidance component of the VA hypothesis reflects the tendency of anxious individuals to avoid directing their attention to the location of a threat object after that object has been attended previously within a perceptual episode. The notion of avoidance has received some support from studies that incorporate the dot-probe paradigm. For example, socially anxious participants responded more slowly to probes in the same position as threat-relevant compared to neutral stimuli presented for 500 ms

(Chen, Ehlers, Clark, & Mansell, 2002; Mansell et al., 1999; Vassilopoulos, 2005), suggesting avoidance of social threat information. However, trait anxious individuals demonstrated avoidance of threatening pictorial stimuli only at 1500 ms, while responding *faster* to probes in the same location as threat stimuli presented for 500 ms (Mogg et al., 2004). These potentially conflicting results highlight the problem inherent in sampling attentional allocation at a single time point; processing (i.e., shifts) that occurs before or after the time point is missed.

Another problem related to the interpretation of dot-probe results as avoidance (or vigilance) concerns the calculation of the attentional bias index (i.e., subtraction of mean RT to anxiety-relevant stimuli from mean RT to neutral stimuli): negative values of this index are said to reflect avoidance, whereas positive values are said to reflect vigilance (e.g., MacLeod et al., 1986). Thus, vigilance and avoidance are not measured independently, although they are conceptualised as independent processes that theoretically both may operate at different time points within the same episode.

Several eye-tracking studies provide the only unambiguous demonstrations of early vigilance *and* later avoidance within single perceptual episodes (Calvo & Avero, 2005; Hermans, Vansteenwegen, & Eelen, 1999; Pflug-shaupt et al., 2005; Rinck & Becker, 2006). This work represents a significant advance in the study of attentional processing in anxiety, as each study provides a continuous window onto behavioural mechanisms as they unfold in real time. Stimulus configuration and content varied in these experiments, although initial fixations and subsequent attentional allocation of overt attention were measured in each.

In one investigation, spider phobics and controls did not differ in initial allocation of overt attention to spider stimuli during early viewing; however, consistent with the avoidance hypothesis, spider phobics fixated threat stimuli significantly less than controls during later viewing (Hermans et al., 1999). Two other studies revealed early vigilance and later avoidance of threat-relevant stimuli in spider phobics (Pflugshaupt et al., 2005; Rinck & Becker, 2006). Finally, in addition to vigilance and later avoidance of emotional scenes, trait-anxious participants also displayed longer gaze duration on aversive scenes early in viewing (Calvo & Avero, 2005). Longer gaze duration is also consistent with the AM account, as high-anxious individuals may be showing difficulty disengaging from anxiety-relevant information.

Together, these results provide substantial evidence of differential overt attentional processing of threat-relevant information in anxious individuals. The results also highlight the value of eye-tracking technology in this line of research; unlike paradigms such as the dot-probe, eye-tracking allows the independent measurement of both vigilance and avoidance through the

continuous monitoring of fixations and saccades in the presence of anxiety-relevant stimuli.

Covert orienting.   The first component of the AM hypothesis is covert orienting, or directing attention to a stimulus without movement of the eyes. As discussed earlier, covert shifts to an object or location occur within approximately 100 ms, and the AM hypothesis asserts that differential orienting to threat does not operate on this timescale. The *cue validity paradigm* (Posner et al., 1980) measures covert spatial allocation of attention and has been used to examine initial orienting of attention. In contrast to the dot-probe paradigm, only one stimulus is presented at a time in the cue validity task, which allows isolation of the orienting mechanism in the absence of stimulus competition. Participants initially fixate on a central point on the screen. A single cue stimulus is presented to the right or left of fixation. The cue offsets, a target stimulus appears in either the cued or the non-cued location, and reaction time for target identification is assessed. The target appears in the valid location (i.e., the same position as the cue) on most trials (e.g., 75%). The high probability of a target in the cue location trains subjects to attend preferentially to the cued location. The detection of targets at the cued location therefore is typically faster and more accurate than at the uncued location. Designs in which non-predictive cues are used (e.g., 50% valid trials, 50% invalid trials) do not provide an incentive to the participant to use the cue, as targets appear equally often in cued and non-cued locations. For such non-predictive designs, although facilitation of attention at the cued location is observable at SOAs up to ~ 250 ms, the pattern reverses after ~ 300 ms, such that poorer performance at the cued location is observed due to inhibition of return (e.g., Fox et al., 2002; Posner, Rafal, Choate, & Vaughan, 1985; Stoyanova, Pratt, & Anderson, 2007). It is therefore necessary to probe early to observe orienting in tasks with a 50/50 split, whereas predictive designs (e.g., 75–80% valid trials) motivate participants to continue to attend to the cued location.

The cueing paradigm provides a measure of enhanced orienting of attention to threat-relevant stimuli. At very short SOAs that allow an orienting shift to a location but are not long enough to allow a second shift away from the location (e.g., 100 ms to 200 ms), faster response times to threat-relevant stimuli compared to neutral stimuli in the valid (cued) location would reflect faster orienting to threat. One study did not find differences in orienting attention to threatening stimuli between high and low trait anxious subjects at 150 ms SOA (Fox et al., 2001). The absence of effects of threat on orienting speed may reflect a general insensitivity to stimulus meaning in the orienting of attention to an abruptly appearing visual cue (Stolz, 1996). A limitation of this approach, however, is that differences in orienting were sampled only at a single point in time: 150 ms

after the onset of the cue. This raises the possibility that differences in orienting speed were present but just not at the time that the target was presented. Consider the possibility that shifting attention covertly to a threatening stimulus takes 90 ms, on average, and shifting attention to a neutral stimulus requires 120 ms, on average. Probing attention at 150 ms after cue onset is unlikely to reveal differences in orienting speed, because the shift of attention would already have been completed for both stimulus types when the target appeared. To conclude confidently that the speed of covert shifts does not differ on the basis of threat, multiple SOAs must be tested within the range of plausible shift times (approximately 50–150 ms).

Covert disengagement.   Rather than speeded covert orienting to threat, the AM hypothesis asserts that anxious individuals experience difficulty with covert disengagement. On invalid cue trials within the Posner cueing paradigm, attention must be disengaged from the cued location and shifted to the uncued location. The cueing effect is the RT for target discrimination on invalid trials minus the RT on valid trials (i.e., the difference in disengagement RT controlling for speed of initial orienting), which reflects the efficiency of disengaging attention from the cued location and re-orienting it to the target location. Researchers can use this paradigm to observe whether delayed disengagement from threat-relevant cues leads to longer RTs to targets in the invalid location. The cueing paradigm has been used to examine delayed disengagement in subclinical anxiety: compared to controls, high trait-anxious participants showed longer response times for detecting targets following invalid angry face cues (Fox et al., 2001), general threat pictures (Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Yiend & Mathews, 2001), and emotional faces (Fox et al., 2002). One recent study with clinical anxiety found difficulty with disengagement from threat-relevant stimuli in social phobia (Amir, Elias, Klumpp, & Przeworski, 2003). Combined, the results suggest that anxious individuals' attention is captured and maintained by threat-relevant information, leading to delayed disengagement.

One limitation of the cuing paradigm as a means to examine disengagement from threat-relevant objects is that the cue stimulus is removed before the onset of the target. Thus, participants are disengaging attention from a location where a threat-relevant stimulus had appeared rather than disengaging attention from the threat-relevant stimulus itself. A better method requires the continued presence of the threat-relevant information when the target appears, so that participants must disengage attention from the threat-relevant stimulus. One such paradigm was presented by Fox and colleagues (Fox et al., 2001, Experiment 5). For this task, the critical stimulus (e.g., neutral or threatening word) appears at fixation, followed by the presentation of a target (e.g., "%" or "&") in the periphery. Participants first attend

to the central stimulus, and then they must disengage covert attention from this stimulus in order to shift attention to the target. The central stimulus remains visible throughout the trial. Whereas the index of disengagement for the Posner cueing paradigm is the difference in the cueing effect between threatening and neutral stimuli, here disengagement is indexed by mean RT for target discrimination on all trials for each stimulus type. With word stimuli at fixation, state-anxious subjects displayed more difficulty with disengagement from threat versus neutral or positive words (Fox et al., 2001), and high trait anxious individuals also displayed difficulty disengaging from fearful faces relative to sad, happy, or neutral faces (Georgiou et al., 2005). These results provide strong additional support for the hypothesised difficulty with covert disengagement.

In general, tasks such as the cueing paradigm and the disengagement paradigm utilised by Fox et al. (2001) are the optimal measurement paradigms when the question of interest involves the initial allocation of covert attention to a particular spatial location or covert disengagement from a stimulus before additional covert shifts are possible. Of particular importance to experimental design are the use of SOAs that are consistent with the timescale of covert orienting, single cue presentation to ensure isolation of the mechanism of interest, and elimination of trials with eye movements in order to rule out the effects of overt attention.

Over timescales more typical of real-world behaviours, researchers utilising visual search paradigms have also provided potential evidence of difficulty with the withdrawal of attention from threat-relevant information in anxiety. Several previously discussed studies found that the presence of a threat-relevant distractor slowed RTs for non-threat target detection (Miltner et al., 2004; Rinck et al., 2005), which could be interpreted as difficulty with disengagement. Because covert shifts precede overt shifts, these results also could reflect difficulty with covert disengagement.

We also note that tasks capable of isolating covert attentional processing, such as the cueing task variants, may be fundamental to efforts to utilise neuroimaging techniques to isolate the neural activation associated with attentional processing. Overt eye movements can limit the detection of neural activation by producing excessive noise in the haemodynamic response in adjacent areas of the orbitofrontal cortex. Also, as eye movements are associated with activation in a network of brain areas, differentiation of activity in the relevant regions can be confounded during subsequent motion correction procedures (e.g., Beauchamp, 2003). Tasks measuring covert shifts of visual attention, therefore, are ideally suited to techniques such as functional magnetic resonance imaging to examine the neural correlates of attention in anxiety.

SUMMARY

In general, the empirical evidence supports our suggested resolution to the apparent contradictions between the VA and AM hypotheses of attention and anxiety, such that both largely are supported by the data. Returning to our original example of attentional processing of threat in social phobia, we outline the theorised operation of attentional mechanisms, the relevant recommended measurement paradigms, and the associated experimental considerations in Table 1. We retain the timescale of Figure 1 in the table. On timescales that involve multiple eye movements, and when multiple stimuli compete for attention, anxious individuals often display early vigilance for and later avoidance of threat-relevant stimuli, as shown by studies incorporating visual-search variants and eye-tracking technology. On the shorter timescales characteristic of covert shifts of attention to single objects, the available evidence supports the assertions of the AM hypothesis. Anxiety does not appear to influence the speed of initial covert shifts of attention (although this conclusion rests on limited evidence), but anxiety does influence the dwell time of attention on an object, making disengagement from threat stimuli difficult.

ADDITIONAL EXPERIMENTAL CONSIDERATIONS

The translation of measurement paradigms from vision science for testing the AM and VA hypotheses also requires diligence regarding methodological issues such as stimulus selection. Two common problems with stimulus set development are evident in many studies. First, the stimuli developed by cognitive researchers to study basic visual attention typically do not correspond well to the stimuli encountered in the world. While this is preferred in research that addresses basic visual processing, the measurement of attentional processing in individuals with disorders requires stimuli that more closely approximate the contexts in which symptoms are most distressing. Tasks that rely upon word stimuli therefore often are less relevant for this population, as, for example, a spider phobic rarely sees the word "spider" appear in the kitchen. That is, one general assumption about visual attentional processing in anxiety is that anxiety-relevant stimuli in the world are percepts, such as a frown on someone's face to a social phobic, or a smudge of dirt to someone with obsessive-compulsive disorder (OCD). While semantic processing of the percepts is also problematic for anxious individuals, the study of basic visual attentional processing is concerned with the selection of perceptual information. It follows that the bulk of the existing research examining visual attention and anxiety relies heavily upon anxiety states and disorders such as animal fear or phobia, or social phobia,

TABLE 1
Overview of attentional mechanisms, recommended measurement paradigms, and associated experimental considerations

	Vigilance	Covert orienting	Overt shift	Covert disengagement	Avoidance
Real-world Example	On entering room, scan for frowning face.	Shift attention to frowning face.	*Move eyes to frowning face.*	Remove attention from frowning face.	Avoid moving eyes to previously located frowning faces; leave room.
Recommended measurement paradigms	Eye tracking (e.g., Pflugshaupt et al., 2005), visual search (e.g., Öhman et al., 2001)	Posner cueing paradigm (e.g., Fox et al., 2001)		Fox et al. (2001; Experiment 5) disengagement paradigm	Eye tracking (e.g., Pflugshaupt et al., 2005), visual search (e.g., Miltner et al., 2004)
Experimental considerations	Multiple seconds of viewing early in perceptual episode. Presence of multiple stimuli in competition, with extended free viewing among all possible stimuli. DV is probability/speed of fixating or finding threat objects relative to non-threat objects.	Very short timescale (50–150 ms SOA). Isolation of stimulus to which attention is being oriented (e.g., presentation of a single threat/non-threat picture to which attention must be oriented). DV is difference in RTs on valid trials for contrasting stimulus types.		Timescale of attentional dwell time on an object ($\sim$200–800 ms). Isolation of stimulus from which attention is being disengaged (e.g., presentation of a single threat/non-threat picture from which attention must be disengaged). DV is difference in RTs for contrasting stimulus types for discrimination task.	Examined later in viewing, after threat stimuli have been identified and located. Presence of multiple stimuli in competition, with extended free viewing among all possible stimuli. DV is probability/speed of returning gaze to previously fixated threat objects relative to non-threat objects; distance of gaze from threat objects relative to non-threat objects.

because the most efficient experimental designs incorporate circumscribed visual stimuli that are common across participants. A caveat: it also might be the case that word stimuli are the optimal choice for the examination of the role of attentional processing in some anxiety disorders. For example, in GAD, threatening information may be more conceptual than perceptual, such that word stimuli are most appropriate.

Second, inattention to stimulus valence and emotionality issues can cloud the interpretation of results (Mathews & Klug, 1993; Ruiz-Caballero & Bermudez, 1997). Studies frequently compare the processing of threat-relevant stimuli to neutral stimuli and/or positive stimuli without including negative, non-threat stimuli, for example. The effects may represent participants' sensitivity to negative valence or stimulus emotionality, rather than anxiety relevance (cf. Keil & Ihssen, 2004). Future work should continue the current trend toward the use of photo stimuli to better approximate real-world threat stimuli, and also include the proper controls for valence and emotionality.

FUTURE DIRECTIONS

We have discussed the ways in which the translation of the vision science approach to the examination of the role of attention in anxiety can improve our understanding of the component mechanisms of problematic perceptual processing. As mentioned in the discussion of the basics of attention, several fundamental questions regarding the nature of attention are relevant to this goal, but have yet to be fully examined in clinical science. These questions concern the degree to which attention is necessary for the processing of perceptual information, as well as the degree to which selection can be attributed to stimulus features versus individual characteristics. Specifically, the relevant issues in anxiety are (1) whether anxious individuals can process threat, and presumably experience symptoms, without attending to the threat stimulus, and (2) the interaction between features of threat-relevant stimuli (stimulus-driven, or bottom-up processing) and the attentional set of the individual (i.e., propensity to seek out perceptual information consistent with threat, or top-down processing) in the selection of information. In addition, the degree to which problematic visual processing of threat-relevant information is influenced by top-down processing, and therefore may be modifiable as a treatment strategy and/or a treatment outcome, is of particular relevance to clinical science. In discussing these avenues for further research, we also note the recent relevant work in neuroscience; although neuroimaging has yet to be employed to examine the particular questions addressed by the integrated VA and AM hypotheses, converging evidence from neuroimaging studies both provides additional support for the

conclusions of the behavioural studies and points to very important areas for future work.

PRE-ATTENTIVE PROCESSING

We have discussed the consequences of attending to an object, but what is the nature of visual processing in the absence of attention? This issue traditionally has been couched as a debate between early and late selection theories of attention (Broadbent, 1958; Deutsch & Deutsch, 1963; Treisman & Gelade, 1980). The former claims that selection occurs fairly early in vision, such that unattended objects are not processed beyond early perceptual analysis and therefore are not identified. The latter claims that all visible objects are processed to the level of meaning prior to selection; the object with the most salient or pertinent meaning is then selected. Although it is clear that selection can occur at multiple levels in the visual system (Luck, Woodman, & Vogel, 2000), the preponderance of evidence suggests that, consistent with early selection theories, objects that do not receive perceptual-level attention are not processed to the level of meaning. When the spatial distribution of attention is limited to a centrally presented object, the meanings of other visual objects are not activated (Lachter, Forster, & Ruthruff, 2004; Lavie, 1995). Even highly familiar and personally relevant objects, such as one's name, do not appear to be identified when attention is exclusively directed elsewhere (Harris & Pashler, 2004).

The issue of whether personally relevant stimuli (such as spiders for spider phobics) are identified without attention has been a topic of recent research in the literature on anxiety and attention. The strongest potential evidence for pre-attentive processing of threat relevance comes from the visual search experiments of Öhman et al. (2001). The time necessary to find spiders among neutral stimuli was independent of set size (i.e., spiders were found to "pop out" of the display), suggesting pre-attentive processing of threat-relevant objects. However, Lipp and colleagues (Lipp et al., 2004) found no advantage for individuals high in snake or spider fear. In a second study with participants unselected for fear status, they found highly efficient search not only for spiders but also for other animals that pose no threat, casting into doubt special pre-attentive processing of threat. In addition, Cave and Batty (2006) have argued that search in the Öhman et al. study was driven by perceptual-level differences between spiders and distractor stimuli rather than by differences in meaning and threat. Thus, the behavioural evidence, although not conclusive, suggests that threat-relevant information is not processed pre-attentively.

Related recent work utilising neuroimaging techniques provides interesting converging evidence regarding potential pre-attentive processing

of anxiety-relevant stimuli. Researchers continue to debate whether threat information can be detected without attention (e.g., Vuilleumier, Armony, Driver, & Dolan, 2001), or whether even minimal attentional resources are required for threat detection (e.g., Anderson, Christoff, Panitz, DeRosa, & Gabrieli, 2003; Bishop, Duncan, & Lawrence, 2004b; Okon-Singer, Tzelgov, & Henik, 2007; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). The most recent findings suggest that some degree of attention is required for amygdala activation, which generally is accepted as the brain's gateway for emotional processing (e.g., Pessoa, Japee, Sturman, & Ungerleider, 2006). When a central task requires all available attentional resources, no amygdala activation to task-irrelevant threat information is observed (e.g., Bishop, Jenkins, & Lawrence, 2007; Pessoa et al., 2006).

Thus, the available evidence suggests that threat-relevance is not processed pre-attentively. The absence of evidence of pre-attentive processing of threat has a bearing on the longstanding automaticity question with respect to the processing of threat stimuli. Threat processing does not appear to meet the criteria of automaticity as originally defined (i.e., processing that is involuntary, unconscious, and capacity free) (e.g., Schneider & Shiffrin, 1977). Processing of threat appears to be voluntary in the sense that top-down goals (e.g., searching for spiders or avoiding looking at spiders) strongly influence perceptual interaction with anxiety-related stimuli. Threat processing is certainly available to consciousness, and threat processing requires some attentional capacity. However, there are likely to be individual differences in the attentional resources required to identify threat-relevant stimuli. For example, phobics might require fewer attentional resources than non-phobics to detect the presence of a spider, consistent with the finding that familiar words (such as one's name) require fewer attentional resources for identification than non-primed words (Treisman, 1960). Future work might seek to determine if, and to identify the conditions under which, the detection threshold shifts in anxious individuals.

ATTENTIONAL CONTROL

Earlier we discussed the role of bottom-up stimulus characteristics that can capture available attention. The degree to which anxiety-relevant stimuli capture attention in this bottom-up manner, as opposed to being assigned selection priority due to top-down attentional set, remains to be determined. Neuroscientific evidence is mounting for separate systems for top-down and bottom-up processing (e.g., Corbetta & Shulman, 2002), and the current behavioural evidence suggests that anxious individuals may experience decreased inhibitory control over attention to threat-relevant stimuli, which implicates impaired top-down functioning. Neuroscientists conducting

examinations of differential processing of threat have addressed individual differences in the degree to which anxiety status is associated with the initial amygdala response, as well as the degree to which pre-frontal functioning (i.e., executive control) is impaired among anxious participants (e.g., Bishop, Duncan, Brett, & Lawrence, 2004a; Carlsson et al., 2004). For example, one fMRI study with unselected participants examined the moderating role of self-reported state anxiety in neural responses to threat stimuli, and found that higher state anxiety is associated with reduced recruitment of executive control areas in the presence of task-irrelevant threat stimuli (Bishop, Duncan, Brett, & Lawrence, 2004a). Additionally, a positron emission tomography (PET) study revealed that both animal phobic and non-phobic participants exhibited initial amygdala activation in response to threat stimuli; however, this activation persisted in phobic individuals, whereas non-phobic individuals showed subsequent deactivation of amygdala replaced by activation of executive control areas (Carlsson et al., 2004). Data from both studies support the notion that anxious individuals experience decreased cognitive control, or decreased ability to inhibit attentional processing of threat. The evidence also provides potential support for the AM hypothesis; prolonged neural recruitment of the amygdala in anxious individuals supports the notion of maintenance of attention to threat.

Difficulty with inhibition of threat information may be due to problematic conflict monitoring (i.e., processing of discrepancy between task demand and task-irrelevant distractors) and resolution. A recent fMRI study showed that the magnitude of conflict between emotional distractor stimuli and task demand predicted the degree of activation in amygdala and prefrontal areas, whereas the resolution of that conflict was associated with increased activity in anterior cingulate cortex and decreased activation in the amygdala (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006). This finding dovetails with other research showing increased activation in anterior cingulate cortex in response to infrequent threat distractors in all participants; as expectancy of threat cues was established, anxious participants recruited this area less, demonstrating decreased control over threat processing (Bishop et al., 2004a).

Additional recent fMRI research highlights the role of expectancy in the processing of emotional visual information. In an expectancy task in which emotional and neutral pictures were always preceded by accurate expectancy cues (e.g., up arrow for emotional, right arrow for neutral), researchers found increased activation in prefrontal, midbrain, and amygdala regions (Bermpohl et al., 2006). Key to this finding is that increased activation did not occur in response to the expectancy cue itself, but only during subsequent picture presentation. Although participants in this study were not selected for anxiety status, the implications for anxiety are consistent

with what clinicians know: anticipation of an anxiety-relevant stimulus predisposes the anxious individual to a more intense response if and when such a stimulus is detected. Further research is necessary to determine whether expectancy effects operate during vigilance as presented by the VA hypothesis, as well as to clarify the degree to which and the conditions under which impaired top-down processing drives preferential selection of threat information. Such work has clinical implications; highly effective exposure-based therapies for anxiety may operate through the modification of attentional set, or the degree to which anxious individuals display a top-down tendency to expect, and/or to seek, anxiety-relevant information.

TREATMENT IMPLICATIONS

Cognitive-behavioural treatments have been shown to be remarkably effective in treating anxiety disorders (e.g., Butler, Chapman, Forman, & Beck, 2006), although a clear picture of the perceptual mechanisms underlying change is less established. The VA and AM hypotheses, in concert with their associated measurement paradigms, offer great potential for a comprehensive understanding of the mechanisms of attentional processing that contribute to the onset, maintenance, and effective treatment of anxiety. Several elegant studies offer preliminary support for a causal role of visual attentional processing in anxiety and suggest the use of experimental paradigms as treatment tools (MacLeod, Campbell, Rutherford, & Wilson, 2004; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002; Mathews & MacLeod, 2002).

In two studies, participants who scored in the mid-range of trait anxiety were randomly assigned to be trained to attend to negative or neutral word stimuli using the dot-probe paradigm. Over the course of training, participants' response latencies for probe detection became significantly shorter (i.e., faster) for the stimulus category to which they were trained to attend, relative to the non-trained category. When participants subsequently completed a stressful task and then rated their current mood state, those in the attend-neutral condition rated their mood state as significantly less anxious and depressed than those in the attend-negative condition. The authors concluded that, for individuals with mid-range trait anxiety, attending to neutral rather than negative information reduces vulnerability to negative affect under stress (MacLeod et al., 2002). That is, rather than directly causing negative mood, the attend-negative training task enhanced vulnerability to a negative stress response. Participants in these studies were selected for their reported mid-range levels of trait anxiety; it is expected that the enhanced vulnerability would be more pronounced in high-anxious individuals or those with anxiety disorders.

Additional recent research has begun to incorporate the above findings into interventions. One set of studies employed similar attention training procedures with high trait anxious participants (Rutherford, MacLeod, & Campbell, 2002). Through nine training sessions over three weeks, the experimental group was trained to attend to neutral stimuli, and the control group completed trials without a training contingency. The experimental group showed a significant reduction in trait anxiety scores after the three weeks, whereas the control group showed no change. Results of unpublished work also showed decrements in social anxiety symptoms for a clinical sample that participated in disorder-specific attention retraining compared to no-retraining controls (in MacLeod et al., 2004).

Although the results of studies that utilise retraining as intervention are quite promising, the particular task used in these studies (i.e., the dot-probe task) precludes precise interpretation of the operating mechanisms. In other words, although the evidence supports the role of preferential attentional processing as the mediator of increased emotional vulnerability, we know neither whether the specific mechanism of intervention involved differential allocation or removal of attention from anxiety-relevant information, nor whether retraining targeted covert as well as overt processing. Clinically, we are pleased when anxious individuals experience reduced distress, regardless of specific mechanism. On the other hand, enhanced precision in our theoretical and measurement models will benefit the development of effective alternative or adjunct treatments. Thus, future research might evaluate the treatment utility of building response contingencies into these measurement paradigms. For example, if vigilance for threat leads to symptom onset and maintenance, participants could be trained to avoid searching for threat stimuli among other competing stimuli by constructing a paradigm in which attending to threat stimuli was detrimental to task performance. For example, if threat stimuli were never targets in a repeated visual search task, participants would have direct incentive to avoid searching for threat, potentially producing a reduction in the prevalence of threat-vigilant behaviour. These and similar manipulations could facilitate efforts to identify the causal role of the subcomponent mechanisms of attentional processing in anxiety, thus providing greater efficiency in the design of retraining interventions.

CONCLUSIONS

We have argued that investigation of the role of visual attentional processing in anxiety requires a mechanistic approach that incorporates the perspective of contemporary vision science into the development and

evaluation of theoretical and measurement models. In particular, we recommend more work that explicitly takes into account the fundamental distinctions outlined by vision scientists, as well as the phenomena involved in extended periods of viewing. Our examination of the theoretical foundations and measurement strategies of the VA and AM hypotheses illustrates the degree to which the vision science perspective enhances our understanding of the role of visual attention in anxiety; indeed, from this perspective the two hypotheses are not incompatible. Although the language commonly used to discuss the two appears to put them in opposition, the two sets of mechanisms implicated by the hypotheses apply to processing operating on different time scales and under different stimulus conditions. The AM hypothesis accounts for rapid shifts of covert attention to and away from single objects, and the VA hypothesis is most applicable to attentional biases that occur in the presence of stimulus competition over the longer time scales characteristic of overt behaviour.

In general, the available evidence supports an integration of the VA and AM hypotheses; both the vigilance and avoidance mechanisms that occur in the presence of stimulus competition on a longer timescale have been demonstrated, and a growing body of evidence also provides support for covert difficulty with disengagement of attention in anxiety. The most compelling evidence for overt vigilance and avoidance has been shown using eye-tracking technology, which allows continuous measurement of attentional allocation over multiple seconds of viewing (e.g., Pflugshaupt et al., 2005). The disengage component of covert attentional allocation, which necessarily occurs on a short timescale, has been supported by variants of the Posner cueing paradigm (Posner, 1980), including the particularly elegant design that ensures measurement of disengagement from the threat-relevant stimulus itself (Fox et al., 2001).

Adopting these theoretical and measurement approaches to the examination of the role of visual attention in anxiety also enhances our ability to answer questions of longstanding interest regarding basic perceptual processing, such as the relative balance of top-down and bottom-up influences on attention and the limits of attentional control. We are aided in this effort by recent advances in neuroscience, and we anticipate future work that examines the neural correlates of the behavioural work in this area. Finally, although it is quite important to understand the component processes of attentional processing in anxiety, we must not lose sight of the fact that these components are part of a larger set of behaviours that are characteristic of disorder and therefore are targets for modification. To this end, clinical scientists are well-situated to continue the process of translation by integrating attention paradigms into clinical research in order to better

understand the mechanisms of visuo-spatial processing in anxiety, enhance diagnostic precision, and examine the benefits of attentional retraining for symptom reduction.

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