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Anxiety and deficient inhibition of threat distractors: Spatial attention span and time course

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We investigated whether anxiety facilitates detection of threat stimuli outside the focus of overt attention, and the time course of the interference produced by threat distractors. Threat or neutral word distractors were presented in attended (foveal) and unattended (parafoveal) locations followed by an unrelated probe word at 300 ms (Experiments 1 and 2) or 1000 ms (Experiment 2) stimulus–onset asynchrony (SOA) in a lexical decision task. Results showed: (1) no effects of trait anxiety on selective saccades to the parafoveal threat distractors; (2) interference with probe processing (i.e., slowed lexical decision times) following a foveal threat distractor at 300 ms SOA for all participants, regardless of anxiety, but only for high-anxiety participants at 1000 ms SOA; and (3) no interference effects of parafoveal threat distractors. These findings suggest that anxiety does not enhance *preattentive* semantic processing of threat words. Rather, anxiety leads to delays in the inhibitory control of *attended* task-irrelevant threat stimuli.

Keywords: Anxiety; Attention; Distractors; Eye movements; Parafoveal; Threat.

Theories of anxiety and attentional bias have proposed two major mechanisms by which anxiety affects cognitive processing (Derryberry & Reed, 2002; Eysenck, Derakshan, Santos, & Calvo, 2007; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997). The first mechanism involves threat detection during early automatic processing stages, with the attentional system of anxious individuals (i.e., those high in the personality dimension of trait anxiety) being abnormally sensitive to threat. This leads anxious people to adopt a hypervigilant mode towards threat (Eysenck, 1992, 1997). A second mechanism involves maintenance of attention on the source of threat, which affects later processing stages. Anxious individuals dwell on threat cues, with delays and difficulties in attentional disengagement (Fox & Georgiou, 2005). A meta-analytic review by Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, and van IJzendoorn (2007) has shown that both mechanisms are affected by anxiety: There is some evidence for a preattentive threat detection bias, although the effect size is larger for later selective allocation of attention to threat stimuli.

In the current study, we investigated two extensions of these attentional biases. First, regarding hypervigilance, we addressed the issue of whether anxiety facilitates the detection of threat stimuli outside the focus of overt attention, i.e., when they appear at extrafoveal locations in the visual field. There is considerable evidence for a lowered *temporal threshold* mechanism involved in hypervigilance, with high-anxiety individuals detecting threat words presented subliminally to a greater extent than nonanxious individuals (see Mayer & Merckelbach, 1999). This effect has been found even when threat words are displayed

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too briefly, and/or backwardly masked, to be read or reported (MacLeod & Rutherford, 1992; Mogg, Bradley, & Williams, 1995). In contrast, the possibility of a hypervigilance mechanism involving the broadening of the *spatial* attentional span in high-anxious individuals has been scarcely investigated and therefore deserved further research in the current study. Presumably, if such a mechanism exists, it would permit processing of threat stimuli outside the focus of visual attention, i.e., stimuli that are more eccentric in the visual field.

Second, regarding the issue of attentional dwelling on threat stimuli, we investigated the time course of a deficient inhibitory control mechanism for threat distractors (both within and outside the focus of attention). In previous research, the role of anxiety on the inhibition of threat distractors has been investigated using mainly the emotional Stroop paradigm, where the relevant task involves naming the colour in which threat-related or neutral words are printed, while trying to ignore the word meaning (which thus becomes a task-irrelevant distractor). High-anxious individuals generally perform more slowly than low-anxious individuals when threat words are presented (see Bar-Haim et al., 2007; Williams, Mathews, & MacLeod, 1996). This suggests that anxiety impairs the ability to inhibit task-irrelevant threat processing. Nevertheless, in emotional Stroop tasks the relevant stimulus (word colour) and the distractor (word meaning) appear *simultaneously*, and so this paradigm serves to assess susceptibility to *concurrent* interference. In a complementary approach involving the presentation of a distractor *followed by* a task-relevant word, we aimed to determine whether interference *remains after* the threatening stimulus has disappeared, and for how long.

The processing of threat-related words outside the focus of overt attention has been investigated using a lexical decision task in a repetition priming paradigm (Calvo, Castillo, & Fuentes, 2006; Calvo & Eysenck, 2008). A threat-related, neutral, or positively valenced probe word was preceded by a parafoveal prime word (2.2° away from fixation; 150 ms display) which was identical or unrelated to the probe. In the Calvo et al. (2006) study, the effect of emotional *state* was examined. Results showed facilitation in lexical decision times for probe threat words if primed by an identical (relative to an unrelated) parafoveal word, when a negative emotional state (anxiety or sadness) was induced by means of unpleasant visual scenes prior to the word task. Calvo and Eysenck (2008) investigated the effects of *trait* anxiety. Parafoveal prime threat words facilitated lexical decision responses to identical (vs. unrelated) threat words for individuals high in trait anxiety. Nevertheless, although these selective priming effects appeared for threat (in comparison with positive and neutral) words, the repetition priming paradigm does not allow us to disentangle semantic from orthographic effects. Repetition priming served to determine that parafoveal threat words were especially likely to be *detected*, but not *what* type information was obtained from them. An alternative paradigm is needed to demonstrate that *meaning* is extracted from parafoveal threat words.

Interference paradigms are useful for addressing the two major issues that we aim to investigate, i.e., the effects of anxiety on the semantic processing of threat-related words outside the focus of overt attention, and the deficient inhibition of threat distractors. In such paradigms, distractor cues are presented that are unrelated to the probe and, therefore, task-irrelevant. If threat distractors are processed semantically, they will grab attention. As a result, if there is deficient inhibition of attention to the distractor, there will be impaired processing of the probe stimulus presented simultaneously or subsequently. The attention-grabbing power and interference of emotionally negative words has been demonstrated when the words are presented at fixation, for samples of participants unselected as a function of anxiety (Calvo & Castillo, 2005; Harris & Pashler, 2004; Pratto & John, 1991; White, 1996). Such interference with the processing of neutral words presented concurrently or subsequently probably occurs because attention is drawn and/or held by the meaning of the distractor. Accordingly, if high-anxious individuals are more likely than low-anxious ones to process parafoveal threat words semantically, the former will exhibit larger interference effects than the latter when threat (relative to neutral) parafoveal word distractors are presented. In contrast, if only the orthographic codes are processed, then parafoveal threat words will not produce any interference.

Previous research using interference paradigms to investigate the effects of anxiety on parafoveal processing has not produced clear findings. Fox (1993, 1994) used an emotional Stroop task in which colour patches were presented at fixation concurrently with threat words spatially separated from the patch. Fox (1993) found that high-anxious participants exhibited interference with colour naming when threat words were presented, but Fox (1994) did not. Fox, Russo, Bowles, and Dutton (2001) used a cueing procedure. Typically, in this task, a cue (e.g., a threat word) appears at one of two sides of a central fixation point, followed by a target (e.g., a circle) in the precued location (valid trials) or the opposite location (invalid trials). Impaired performance (i.e., longer target localisation times) on invalid trials indicates difficulties in disengagement from the cue word. In the Fox et al. (2001, Exp. 1) study, participants took longer to localise the target when the cue was a threat word than when it was a positive or a neutral word. While this indicates parafoveal capture of attention by the threat words, the interference effect of these words was similar for the high- and the low-anxious participants. Broomfield and Turpin (2005) also used a cueing paradigm and found slowed disengagement (i.e., slower to detect invalidly cued targets) from threat words than from neutral words for both high- and low-anxiety groups, in Experiment 1. However, in Experiment 2, high-anxiety participants showed faster disengagement from threat cue words (i.e., faster to detect invalidly cued targets) relative to neutral words, and low-anxiety participants showed no facilitation or interference.

In summary, no consistent findings have appeared regarding the possibility that anxiety is especially associated with parafoveal threat processing and deficient inhibition of threat word distractors. Clarification of this issue probably requires consideration of the time course of the underlying processes. Fox et al. (2001) used a short 150 ms cue–target stimulus–onset asynchrony (SOA), whereas Broomfield and Turpin (2005) used a 500 ms SOA. It is possible that, at very early stages, the threat meaning is active for most individuals, but that it is inhibited later by those low in anxiety, whereas their high-anxiety counterparts continue to attend to threat. Whereas a 150 ms SOA represents early stages, a 500 ms SOA may represent a time between early and late stages, involving both automatic and strategic processes. If so, at 500 ms from the onset of the threat cue, a mixture of effects may occur. Presumably, clearer strategic effects on attentional dwelling on threat as a function of anxiety only appear later than 500 ms. These speculations indicate the importance of investigating the time course of a deficient inhibitory control mechanism in high anxiety.

With this in mind, we used an interference paradigm in the current study in which the onset asynchrony between a distractor word and a probe word was varied. A threat-related or a neutral distractor were presented foveally (at fixation) or parafoveally (displaced 2.2° of visual angle to the right or left), followed by a foveal neutral probe word for lexical decision at short (300 ms; Experiments 1 and 2) or long (1000 ms; Experiment 2) SOAs. The distractor was always task-irrelevant, as it was unrelated to the probe meaning and form. The critical comparison involves the probe lexical decision latencies when the distractor is a threat word relative to when it is a neutral word. If the meaning of the threat word distractor is processed, it should capture attention and so interfere with the processing of the probe word. This would be reflected in slowed responses to the probe when preceded by a threat distractor, relative to a neutral distractor. A deficient inhibitory control mechanism for threat would manifest itself in slowed responses not only at the short but also at the long SOA for high-anxiety participants, while the interference effect would not occur at the longer SOA for those low in anxiety.

EXPERIMENT 1

Eye movements were monitored while threat-related and neutral words were presented as distractors foveally or parafoveally for 150 ms, followed by neutral probe words at 300 ms SOA. Some studies have demonstrated that individuals high in trait anxiety show a bias in overt orienting (i.e., eye movements) towards threat words outside of foveal vision (Broomfield & Turpin, 2005). Accordingly, to determine that there is truly parafoveal processing of threat words, it is important to prevent eye fixations on the parafoveal distractors (while allowing such fixations in the foveal condition). To achieve this, we used a gaze-contingent-display change technique (see Calvo & Nummenmaa, 2009). With this technique, when the eyes of the participant move away from the fixation point beyond a prespecified boundary, the parafoveal word is replaced by a row of Xs. This ensures that the distractor word cannot be fixated foveally, yet it remains available parafoveally. Hypervigilance will occur if there are more saccades towards the parafoveal threat distractors than to neutral distractors, and/or slower lexical decisions to the probe words following the parafoveal threat distractors than following neutral distractors.

Method

Participants. Sixteen psychology undergraduates high in trait anxiety (12 female) and 16 low in trait anxiety (12 female) participated for course credit. They were selected from a group of 91 students as a function of their high ($M = 54.6$, $SD = 4.4$) or low ($M = 34.4$, $SD = 3.1$), $t(30) = 15.95$, $p < .0001$, scores in the trait scale (ranging from 20 to 80) of the STAI (State-Trait Anxiety Inventory; Spielberger, Gorsuch, & Lushene, 1982). This inventory was administered under nonstressful, nonthreatening conditions (in a large group, anonymously, in a classroom, during a demonstration of the use of questionnaire measures). To encourage honest responses (and minimise the potential influence social desirability) in this self-report measure, each questionnaire was identified by an anonymous code, rather than by the participant's name. Furthermore, the students were told in advance that each would score his/her own responses, and then they would be provided with instructions about how to interpret them. We assumed all this would contribute to reliable trait anxiety assessment.

Stimuli. As target distractors, 48 threat-related words and 48 neutral words were presented (see Appendix). As probes, 96 neutral words were used, all of which were semantically and orthographically unrelated to the distractors. In addition, 48 nonword stimuli (i.e., pseudowords in which one letter of a valid word was changed) were presented as probes, preceded by 48 additional word distractors. The target words have been validated and used in previous studies (e.g., Calvo & Castillo, 2005; Calvo et al., 2006).The threat and the neutral word distractors were matched in length and were practically identical in lexical frequency (threat: $M = 36.96$ occurrences per million; neutral: $M = 36.31$).

Apparatus. The verbal stimuli were presented on a 21-inch monitor with a 120 Hz refresh rate, connected to a Pentium IV computer. Participants' eye movements were recorded with an EyeLink II tracker (SR Research Ltd., Mississauga, Ontario, Canada). The sampling rate of the eyetracker was 500 Hz and the spatial accuracy was better than 0.5°, with a 0.01° resolution in pupil tracking mode. A chin and forehead rest was used at a 60 cm viewing distance from the monitor.

The distractor words (in lowercase) subtended a visual angle between 1.3° and 1.8°, depending on the number of letters (five to seven). The probe string (in capital letters) subtended a visual angle between 1.4° and 2.0°. In the foveal condition, the distractor appeared at fixation at the same time as a string of xx + xx (1.4°) appeared parafoveally. In the parafoveal condition, the string of xx + xx appeared at fixation at the same time as the distractor appeared parafoveally. The distance between the respective centres of the two stimuli (i.e., distractor word and string of xx + xx) was 2.2°. In the parafoveal condition, a gaze-contingent-display change was implemented such that the initial and the last x of the central fixation of xx + xx constituted a boundary. When the centre of the foveal fixation of the viewer crossed these boundaries, the parafoveal word turned to a string of five Xs in a row.

Design and procedure. The design involved a combination of trait anxiety (low vs. high), distractor valence (threat vs. neutral), and distractor location (foveal vs. parafoveal); visual field (left vs. right) of distractor was also included in the parafoveal condition. Anxiety was a between-subjects factor; the others were within-subjects factors. Each participant was presented once with half of the threat distractors and half of the neutral distractors in the foveal condition, and the other half in the parafoveal condition. Assignment of distractors to the foveal and the parafoveal condition was counterbalanced across participants. Each participant was presented with 96 probe word trials, and 48 nonword trials, plus 30 practice trials. The experimental trials were randomly assigned to two blocks and randomly presented within each block for each participant.

Figure 1 depicts the sequence of events on each trial. A central white circle (0.8°) served for drift correction. When the participant fixated this circle, the distractor display appeared for 150 ms, with one foveal word at the centre of fixation or a parafoveal word to the left or right of fixation. Following a 150 ms blank interval, a probe word (or nonword) appeared in the centre, for a lexical decision response. Accordingly, there was a 300 ms distractor–probe SOA. The probe

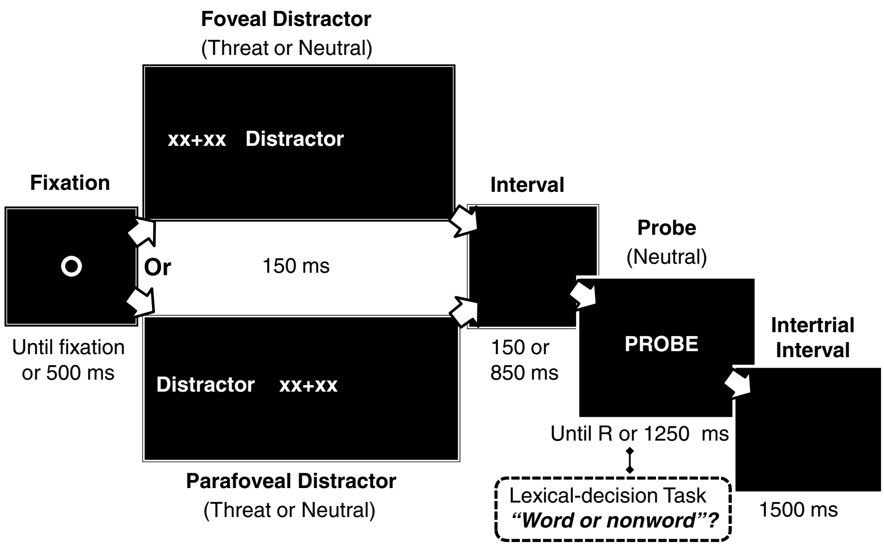

Figure 1. Sequence of events on each trial in Experiments 1 and 2.

remained visible for 1250 ms or until the participant responded whether it was a word or a nonword. Participants responded to the probe as rapidly as possible by pressing one of two keys of a response box. After the response, there was a 1500 ms intertrial interval. Participants were instructed to look at the centre, as the relevant stimulus for lexical decision would appear on that location.

Measures. The following measures assessed eye movements: the probability of initiating a saccade towards the parafoveal distractor, the saccade latencies (i.e., the time to initiate an eye movement from the central fixation point towards the distractor), and the end time (i.e., the time taken to land on the location of the distractor). In the foveal condition, no eye-movement measure was of particular interest, given the short display at fixation. For the probe words, accuracy and reaction times in the lexical decision task served to assess interference effects.

Results

Saccades towards the parafoveal distractors. Saccades were analysed in 2 (anxiety) × 2 (valence of distractor) × 2 (visual field of distractor) ANOVAs. The duration of fixations on the distractor area was also examined when there was any fixation. There was no significant effect on the probability of saccades towards the distractor: all Fs < 1, for anxiety (low $M = 0.131$, high $M = 0.123$), valence (threat $M = 0.128$, neutral $M = 0.126$), and visual field (left $M = 0.124$, right $M = 0.130$). In addition, neither saccade latencies nor the end times of the saccades landing on the distractor location were significantly affected by any factor (all Fs < 1). The mean *start* time of these saccades was 138 ms ($SD = 7.80$), and the mean *end* time was 160 ms ($SD = 10.8$). Given that the parafoveal word was displayed for 150 ms, these results imply, first, that the prime words were parafoveally available (i.e., not yet covered by the gaze-contingent five-X mask) during most of the 150 ms display time, even on the 12.7% of trials with eye movements; and, second, on most of the trials with eye movements, the parafoveal word had actually disappeared (or else it was masked) by the time the fixation landed on the word location, and so the word itself was not fixated. Thus, the conditions allowed for parafoveal processing without foveal processing of the words.

Lexical decision performance on the probe. Response accuracy and latencies of correct responses in the lexical decision task were analysed in two 2 (anxiety) × 2 (valence of distractor) × 2 (distractor location) ANOVAs. Visual field was not included initially, as it was involved in the parafoveal but not in the foveal condition.

Response accuracy was not significantly affected by any factor (M probability of correct responses $= 0.974$; all Fs < 1). A main effect of valence on lexical decision times emerged, $F(1, 30) = 11.76$, $p < .01$, $\eta_p^2 = .282$, which was qualified by a valence by location interaction, $F(1, 30) = 10.97$, $p < .01$, $\eta_p^2 = .268$. Post hoc contrasts were conducted to decompose the interaction. In the foveal condition, responses to probe words were 25 ms slower following threat distractors ($M = 686$ ms) than following neutral distractors ($M = 661$), $t(15) = 5.37$, $p < .0001$, whereas in the parafoveal condition response times were equivalent (-3 ms) following threat ($M = 661$) and neutral ($M = 664$) distractors. The effect of anxiety was not significant ($F < 1$), nor were any of the interactions in which anxiety was involved (all Fs < 1). The mean correct lexical decision times on probe words are shown in Table 1.

We decided to examine further the possibility that visual field made a contribution or modulated the effects of threat words, in view of the evidence of a right visual field advantage in word recognition (Calvo & Nummenmaa, 2009; Kanne, 2002) and in threat word processing (Calvo & Eysenck, 2008). Accordingly, we included visual field (in addition to valence and anxiety) as a factor in a further ANOVA on response times in the parafoveal distractor condition. No significant effects appeared, including interactions with visual field (all Fs < 1). The interference scores (i.e., threat–neutral distractor) on response times to the probe words were close to zero (i.e., no interference) and equivalent when the threat word was presented in the right ($M = -4$ ms) and the left ($M = -2$ ms) visual fields. The interference scores also did not differ as a function of anxiety ($M = -3$ ms for both high- and low-anxiety groups).

Discussion

Threat word distractors in foveal vision interfered with the processing of subsequent neutral words, and this occurred similarly for low- and high-anxiety participants. This can be inferred from the longer lexical decision times on a neutral probe following a threat distractor relative to a neutral distractor. Such a main interference effect of threat words has been frequently reported in prior research using different paradigms, with participants unselected as a function of anxiety (e.g., Pratto & John, 1991; Stormark, Nordby, & Hugdahl, 1995; White, 1996). This suggests that threat words presented at fixation can generally grab attention and interrupt other ongoing processes for most viewers, regardless of anxiety. Nevertheless, this is apparently not consistent with the hypothesis that anxiety is especially characterised by deficient inhibition of threat distractors (Eysenck et al., 2007), or difficulties in disengaging from threat stimuli (Fox & Georgiou, 2005). It is, however, possible that the effects of anxiety depend on the time course of the inhibitory mechanism. In fact, with participants unselected as a function of anxiety, Calvo and Castillo (2005) found that the interference effect of threat distractors occurred at 300 ms SOA (as in the current experiment) but disappeared at 1000 ms SOA. Accordingly, it is important to investigate whether the defective inhibition of threat distractors extends over time for high- but not for low-anxiety individuals. This issue was addressed in Experiment 2, by manipulating the distractor–probe SOA.

In contrast, parafoveal threat words did not cause any interference, even in conditions (i.e., right visual field) that facilitate lexical access (Calvo & Nummenmaa, 2009). This lack of effects cannot be attributed to insufficient capture of cognitive resources by the threat words, as interference did occur when they were presented foveally. It is possible that words were not semantically processed in parafoveal vision and that threat words are not especially likely to be perceived by high-anxiety individuals outside the focus of overt attention. However, this conclusion would be at odds with the hypervigilance hypothesis, according to which anxiety should broaden spatial attention—or the span of effective vision—for threatening stimuli (Eysenck et al., 2007), and also with prior data showing facilitation effects of parafoveal prime threat words on probe threat words, for high anxiety subjects (Calvo & Eysenck, 2008). Given the need to account for such inconsistencies, we conducted Experiment 2.

TABLE 1
Mean lexical decision times (in ms) for probe words as a function of location and valence of distractor word, for low and high trait anxiety groups, in Experiment 1

	Foveal location				*Parafoveal location*			
	Low anxiety		*High anxiety*		*Low anxiety*		*High anxiety*	
Distractor valence	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Threat	680	106	692	103	659	130	662	102
Neutral	662	111	660	100	662	118	665	103

EXPERIMENT 2

Experiment 2 was concerned with the time course of the interference that the processing of foveal or parafoveal threat distractors may produce. We varied the SOA between the distractor and the probe (either 300 or 1000 ms), with the distractor display kept constant at 150 ms. This allows us to examine whether interference involves only initial capture of attention or whether it also affects later attentional engagement. The use of two SOAs permits the exploration of a defective inhibition mechanism for threat-related information, according to which high-anxious individuals show delayed disengagement from threat stimuli. Slowed lexical decision times on the probe words following a threat (relative to a neutral) distractor were assumed to indicate deficient inhibitory control. The prediction is that the interference effects of threat words in high-anxious participants will occur at 1000 ms as well as 300 ms SOA, whereas interference will occur for low-anxious participants only at 300 ms SOA.

Method

Participants. Twenty-four psychology undergraduates high in trait anxiety (18 female) and 24 low in trait anxiety (18 female) participated for course credit. They were selected from a group of 142 students as a function of their high ($M = 54.5$, $SD = 4.0$) or low ($M = 33.4$, $SD = 3.3$), $t(46) = 16.87$, $p < .0001$, scores in the trait scale of the STAI (Spielberger et al., 1982), with the same criteria as in Experiment 1.

Other methodological characteristics. The apparatus, stimuli, design, and procedure resembled those used in Experiment 1, with the following differences. First, no eyetracker was used now, given the negligible number of saccades that landed on the parafoveal word location during the 150 ms display in Experiment 1. Second, a new distractor–probe 1000 ms SOA was added. The distractor word and the string of xx + xx were always presented concurrently for 150 ms, followed by either an 850 ms blank interval (1000 ms SOA) or a 150 ms blank interval (300 ms SOA) before the onset of the probe. The design involved a combination of trait anxiety (low vs. high), SOA (300 vs. 1000 ms), distractor valence (threat vs. neutral), and distractor location (foveal vs. parafoveal). For each participant, half of the threat distractors and half of the neutral distractors were randomly assigned to each SOA condition, with each SOA condition assigned to either the first or the second block in a counterbalanced order. Anxiety was a between-subjects factor, whereas the others were within-subjects factors.

Results

Response accuracy was not significantly affected by any factor (M probability of correct responses = 0.977; all Fs < 1). Mean correct lexical decision times for probe words (see Table 2) were initially analysed in an Anxiety × SOA × Valence × Location ANOVA. The main effects of valence, $F(1, 46) = 16.54$, $p < .0001$, $\eta_p^2 = .265$, and SOA, $F(1, 46) = 43.58$, $p < .0001$, $\eta_p^2 = .486$, with no effects of anxiety ($F < 1$) or location ($p = .22$), were qualified by the following interactions: Anxiety × Valence, $F(1, 46) = 9.63$, $p < .01$, $\eta_p^2 = .173$, Location × Valence, $F(1, 46) = 48.46$, $p < .0001$, $\eta_p^2 = .513$, Anxiety × Valence × Location, $F(1, 46) = 9.44$, $p < .01$, $\eta_p^2 = .170$, Valence × SOA, $F(1, 46) = 12.45$, $\eta_p^2 = .213$, and Anxiety × Valence × SOA, $F(1, 46) = 6.43$, $p < .025$, $\eta_p^2 = .123$.

To examine the meaning of these interactions (see Figure 2), we analysed the effects of valence for each location, SOA, and anxiety group. When threat distractors appeared *foveally* at the shorter (300 ms) SOA, responses to the probe words were slower than when neutral distractors were presented, for both the low-anxious, $t(23) = 4.45$,

TABLE 2
Mean lexical decision times (in ms) for probe words as a function of location and valence of distractor word in the 300 ms and the 1000 ms SOA conditions, for low and high trait anxiety groups, in Experiment 2

	Stimulus–onset asynchrony							
	Foveal location				*Parafoveal location*			
	300 ms		*1000 ms*		*300 ms*		*1000 ms*	
Distractor valence	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Low anxiety								
Threat	669	103	630	97	648	109	641	97
Neutral	644	93	639	99	652	99	647	99
High anxiety								
Threat	686	93	671	93	652	97	643	96
Neutral	653	91	645	90	657	96	647	97

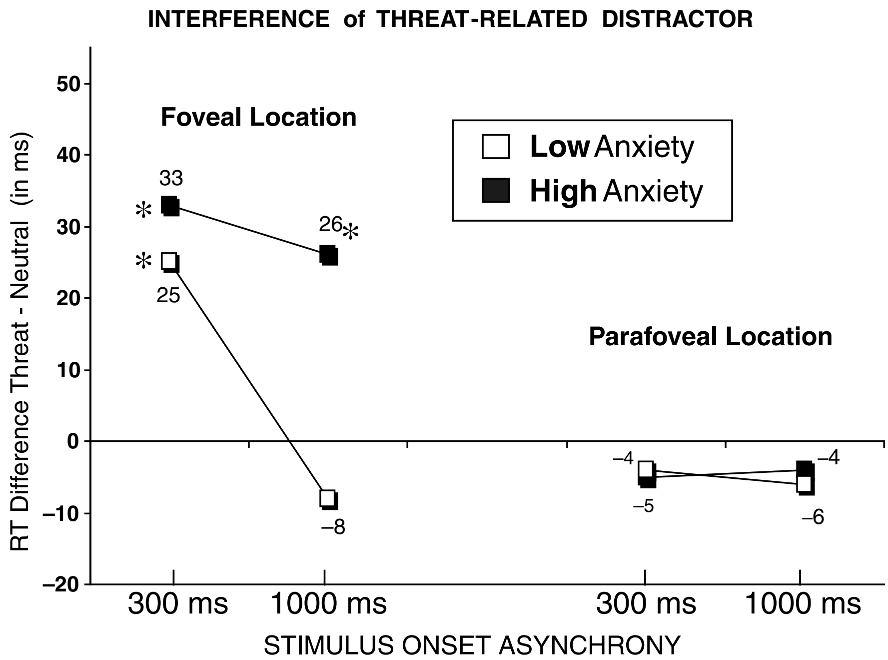

Figure 2. Interference scores (i.e., lexical decision times for the probe following a threat distractor word minus RTs following a neutral distractor). Positive scores indicate interference. Asterisks show significant differences between the threat and the neutral condition.

$p < .0001$, and the high-anxious, $t(23) = 7.10$, $p < .0001$, group. However, at the longer (1000 ms) SOA, this effect remained significant only for the high-anxious group, $t(23) = 4.35$, $p < .0001$.

In contrast, when the distractors were presented *parafoveally*, there was no significant effect of valence at either SOA and for either anxiety group. We further included visual field as a factor in the ANOVA. The interference scores were close to zero (i.e., no interference) when the threat word distractor was presented in the right visual field (M low anxiety = -3 ms vs. high anxiety = -2 ms), and were not different from those in the left visual field (M low anxiety = -7 ms vs. high anxiety = -6 ms). No interaction was significant (Fs < 1).

Discussion

Foveal threat word distractors generally slowed down lexical decision responses to neutral probes at the shorter (300 ms) SOA. This reveals initial attentional *capture* by threat stimuli, which occurs generally for most individuals regardless of anxiety. In addition, foveal threat distractors continued to produce interference at the longer (1000 ms) SOA for high-anxiety participants, but the effect disappeared for low-anxiety participants. This reveals attentional *engagement*, or longer dwelling, on the threat source only for high anxiety individuals. The fact that foveal interference remained for the high-anxious group at 1000 ms SOA confirmed the prediction that this group would be slower to disengage from threat words, which could be either an attentional effect or a response effect. It was as if high-anxiety participants were "cognitively frozen" by the threat distractors, whereas low-anxiety participants could "get rid of" such distractors earlier and reallocate attention to the probe. This is consistent with the hypothesis that high-anxiety individuals are characterised by difficulties in disengaging from threat-related stimuli (Fox & Georgiou, 2005), and that they have deficient inhibitory control of attention to such stimuli (Eysenck et al., 2007). In contrast, parafoveal threat distractors did not produce any interference at either SOA or for either anxiety group, which suggests that threat word meaning was not processed outside the focus of overt attention (see the next section for an explanation of discrepancies).

GENERAL DISCUSSION

The current study has yielded three major findings. First, high trait anxiety was not associated with enhanced saccades towards parafoveal threat word distractors, relative to neutral distractors and to low anxiety. Second, threat distractors appearing at fixation produced immediate interference with the processing of neutral probe words for both high- and low-anxiety groups, but threat distractors produced delayed interference only for those high in anxiety. And, third, threat distractors did not cause any interference when they were presented parafoveally. These findings are relevant to three important issues, respectively: biased overt orienting to threat-related stimuli, deficient delayed inhibitory control of threat distractors, and semantic processing of threat cues outside the focus of overt attention.[1]

Initial orienting and deficient inhibitory control of attention to threat distractors

In their meta-analytic review of attentional bias, Bar-Haim et al. (2007) concluded that two prominent cognitive characteristics of anxiety involve initial preattentive threat detection and later allocation of attention to threat. These characteristics can be linked to the hypervigilance and the deficient inhibition hypotheses, which are central in models of anxiety and cognitive functioning (Eysenck et al., 2007; Fox & Georgiou, 2005; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997). Anxiety would facilitate threat detection through hypervigilance to threat cues, which, once detected, would be difficult to suppress or ignore—even if they are task-irrelevant—due to deficient inhibitory control.

Early threat detection can be accomplished by means of a hypervigilance mechanism through eye movements to threat stimuli appearing outside the focus of attention. Some studies have investigated eye movements to lateralised emotional faces (Bradley, Mogg, & Millar, 2000) or scenes (Calvo & Avero, 2005) as a function of trait anxiety. In the only study with words as stimuli of which we have knowledge, high-anxious participants were more likely to make eye movements to lateralised threat words, relative to nonthreat words (Broomfield & Turpin, 2005). In contrast, in the current study (see also Calvo & Eysenck, 2008), high-anxious participants had no more eye movements to threat than to nonthreat words, and did not make more such movements than low-anxious participants. These empirical discrepancies cannot be attributed to our use of gaze-contingent masking, which might have discouraged participants from looking at the parafoveal words. The reason is that the percentage of trials with (uninstructed) saccades towards the words in our study was higher (13%) than in the Broomfield and Turpin experiments (6%, on average). Accordingly, it is possible that hypervigilance can be accomplished by alternative—though compatible—means: Anxiety could broaden the attentional spatial span through covert attention (and hence no overt saccades would be necessary to process parafoveal words; Calvo & Eysenck, 2008), or anxiety could induce eye-movement scanning through overt attention (Broomfield & Turpin, 2005).[2]

A mechanism of defective inhibition of attention to threat has been investigated by means of task-irrelevant distractors (see Eysenck et al., 2007). In our study, the fact that interference persisted following threat word distractors longer for high- than for low-anxiety participants reveals difficulties in inhibiting attention to threat. This is consistent with research using the emotional Stroop task (see Williams et al., 1996), where

[1]Theory and research on anxiety and cognitive bias has focused on attention to *threat*-related stimuli as a specific characteristic of anxiety. In the current study, we aimed to extend the views on the mechanisms involved, i.e., hypervigilance and deficient inhibition of threat stimuli, and therefore we used threat-related words (and neutral words, for comparison). We might, nevertheless, consider whether the processing of other types of emotional stimuli, mainly positively valenced, is also affected by hypervigilance and attentional control in anxious individuals. Thus far, there is minimal evidence of the involvement of these mechanisms in the processing of positive stimuli, as a function of anxiety (see Bar-Haim et al., 2007). Furthermore, in a related study, Calvo and Eysenck (2008) found no significant differences in positive-word processing between high- and low-anxiety participants.

[2]We have assumed that anxiety-driven hypervigilance can involve broadening of perceptual span to facilitate detection of threatening stimuli appearing eccentrically in the visual field. Although this assumption has received some support (Keogh & French, 1999; Shapiro & Lim, 1989), there is also controversy about it. Positive emotions have been proposed to broaden the scope of attention, whereas negative emotions, including anxiety, could produce narrowing (Derryberry & Tucker, 1994; Fredrickson & Branigan, 2005; see Clore & Huntsinger, 2007, for a review). It must, nevertheless, be noted that, in these studies, broadening and narrowing were conceptualised in a general sense encompassing a wide range cognitive processes; furthermore, attentional span was not strictly defined in terms of the functional field of view, with no manipulation of stimulus eccentricity.

anxious individuals find it difficult to ignore the content of threat words. Our findings add to these studies by showing that threatening information not only can draw attention, but that threat holds attention even when the stimulus is *no longer* present. Whereas in Stroop studies the task-relevant word colour and the task-irrelevant word meaning are presented simultaneously, in the current paradigm, the task-irrelevant distractor was presented *before* the task-relevant probe. Beyond concurrent interference (Stroop studies), we have thus shown *poststimulus* interference. Other paradigms in which threat cue words and probe words are presented in a sequential manner have also provided evidence of defective inhibition in anxiety (Fox et al., 2001; Wood, Mathews, & Dalgleish, 2001; with cue angry faces or unpleasant scenes, see Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Fox, Russo, & Dutton, 2002; and Yiend & Mathews, 2001). The current study makes a contribution by showing the time course of this mechanism, i.e., how threat interferes automatically for all individuals at an initial stage, whereas interference either persists or is controlled at later strategic stages as a function of anxiety.

In summary, of the two major characteristics regarding the processing of threat-related information by high-anxiety individuals, i.e., hypervigilance and early orienting to threat, and later allocation and deficient inhibitory control of attention to threat, we have found clear evidence supporting the latter, but not the former (at least, no selective orienting in *overt* visual attention to threat words).[3] It must, nevertheless, be noted that our study was designed to investigate the role of *trait* rather than state anxiety. Bishop (2009), and Pacheco-Unguetti, Acosta, Callejas, and Lupiáñez (2010) have shown that the effects of trait and state anxiety on attentional mechanisms are not the same. Bishop (2009); see also Bishop, 2007) found high trait anxiety to be linked to impoverished recruitment of prefrontal attentional control mechanisms (especially the dorsolateral prefrontal cortex and the ventrolateral prefrontal cortex) to inhibit distractor processing; furthermore, this effect remained after controlling for state anxiety. In contrast, elevated state anxiety is associated with increased amygdala responsiveness, and therefore hypervigilance to threat (see Bishop, 2007). Also, Pacheco-Unguetti et al. have demonstrated that, whereas state anxiety is associated with an overfunctioning of alertness and orienting in attentional networks, trait anxiety is mainly related to deficiencies in the executive control of attention. This is consistent with our own findings, in that trait anxiety is more related to deficient inhibitory control than to hypervigilance (which might be more affected by state anxiety; see Calvo et al., 2005).

[3]The null effect on anxiety on visual orienting in the current study cannot be attributed simply to the use of words. In a recent study, Derakshan and Koster (2010) recorded eye movements in a visual search task using face stimuli with angry, happy, and neutral expressions. Trait anxiety was not associated with number of fixations or time spent on crowd faces *before* fixating the angry (i.e., threat) targets, thus showing no facilitated orienting to threat. This adds to the debate about the extent to which anxiety affects early threat detection (Bar-Haim et al., 2007).

Semantic versus nonsemantic parafoveal processing of threat words

In spite of the clear interference caused by foveal threat distractors immediately (300 ms SOA; all participants) and with delay (1000 ms SOA; only high-anxiety participants), the same threat words in parafoveal vision produced no interference. If we take the threat vs. neutral interference difference as indicative that threat meaning was processed (see introduction and later), the lack of effects suggests that parafoveal threat words were not semantically analysed by low- or high-anxiety participants. This is in apparent conflict with the findings obtained by Calvo and Eysenck (2008). These authors used a repetition priming paradigm to investigate facilitation effects of parafoveal prime words on the processing of identical versus unrelated probe words. They found faster lexical decision responses for probe threat words following parafoveal threat words for high- than for low-anxiety participants, relative to neutral and positive words. These facilitation effects would demonstrate that threat words are especially likely to be perceived in parafoveal vision by high-anxiety individuals.

It must, however, be noted that repetition priming indicates that the prime words are processed, but does not reveal what kind of information is extracted, that is responsible for the facilitation effects. Although repetition priming is sensitive to word meaning (i.e., the prime–probe semantic relatedness; e.g., Gollan, Forster, & Frost, 1997), it can be influenced by the prime-probe orthographic similarity. In fact, prior research has shown that word form codes are more likely than semantic codes to be obtained parafoveally (see Rayner, 1998). Accordingly, the priming effects found by Calvo and Eysenck (2008) could have been determined more by orthographic similarity rather than by meaning. These authors explicitly acknowledged this possibility as an alternative explanation of the priming advantage for parafoveal threat words in high-anxiety individuals. Furthermore, this orthographic advantage hypothesis is compatible with an additional finding. Namely, in the Calvo and Eysenck study, anxiety was associated with greater familiarity with threat words, and the parafoveal priming effects were significantly reduced when differences in word familiarity were removed. At a more general level, this is also consistent with the suggestion that the preattentional bias to threat words may have more to do with their disproportionate usage in anxious people than with the processing of the actual emotional word valence (see Fox & Georgiou, 2005, p. 11).

Accordingly, it is possible to interpret and integrate the empirical discrepancies between the lack of interference (current study) and the facilitation (Calvo & Eysenck, 2008) effects of parafoveal threat words. High-anxious individuals would be more likely than low-anxious ones to process threat words orthographically due to greater familiarity with them. This would explain why high-anxious participants showed a parafoveal threat priming effect (Calvo & Eysenck, 2008). Due to greater familiarity with threat words, their orthographic form would become more accessible in parafoveal vision and produce repetition priming, i.e., *facilitation* in the processing of an orthographically overlapping probe word. However, the mere orthographic representation of threat words (*not* involving threatening *meaning*—hence, not grabbing attention) would not *interfere* with the semantic processing of an unrelated neutral probe word. Thus, orthographic processing of parafoveal threat distractors would be insufficient on its own to interfere with lexical decisions on unrelated neutral probes (the current experiments), but would be enough to produce repetition priming (Calvo & Eysenck, 2008).

CONCLUSIONS

We investigated two extensions of attentional bias in anxiety: (1) preattentive processing of threat-related stimuli in parafoveal vision, and (2) the time course of defective inhibition of attention to threat distractors. First, the lack of selective orienting to, and interference from, parafoveal threat word distractors suggests that anxiety does not facilitate the semantic processing of threat-related information outside the focus of overt attention, i.e., preattentively or prior to fixation on the words. In contrast, second, anxiety strongly affects attentional engagement on threat content *after* a threat-related stimulus has been fixated. When threat word distractors were presented at fixation, they slowed down lexical decisions on neutral probe words immediately (300 ms SOA) for all participants, but such an interference effect remained at a later stage (1000 ms SOA) only for high-anxiety participants. This suggests anxious people have difficulties in inhibiting attention to threat distractors, even after these are no longer present as stimuli.

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APPENDIX

Threat words and neutral words

Threat words		
Coffin (ataúd)	Poison (veneno)	Rape (violar)
Hate (odiar)	Thief (ladrón)	Suffocation (asfixia)
Fight (pelea)	Alarm (alarma)	Drowned (ahogado)
Tumour (tumor)	Panic (pánico)	Help! (Socorro)
Cruel (cruel)	Cry (llanto)	Malignant (maligno)
Tomb (tumba)	Wound (herida)	Shot (disparo)
Bomb (bomba)	Crime (crimen)	Torture (tortura)
Kill (matar)	Horror (horror)	Stroke (infarto)
Virus (virus)	Suffer (sufrir)	Murder (asesino)
Die (morir)	Terror (terror)	Punishment (castigo)
Pain (dolor)	Jail (cárcel)	Corpse (cadáver)
Fear (miedo)	Cancer (cáncer)	Enemy (enemigo)
Lash (azotar)	Fire! (¡fuego!)	Ill (enfermo)
Viper (víbora)	Blood (sangre)	Danger (peligro)
Mugging (atraco)	War (Guerra)	
Beating (paliza)	Victim (víctima)	
Agony (agonía)	Shoot (fusilar)	
Neutral words		
Hat (gorro)	Bag (bolso)	Beard (barba)
Add (sumar)	Cable (cable)	Ear (oreja)
Poem (poema)	Bird (pájaro)	Bricklayer (albañil)
Walk (andar)	Trial (ensayo)	Broom (cepillo)
Nose (nariz)	Moustache (bigote)	Keyboard (teclado)
Look (mirar)	Shoulder (hombro)	Form (impreso)
Letter (carta)	Tent (tienda)	Concrete (cemento)
Floor (suelo)	Close (cerrar)	Cotton (algodón)
Smooth (alisar)	Bridge (puente)	Track (sendero)
Paintbrush (brocha)	Harbour (puerto)	Pavement (asfalto)
Cheque (cheque)	Theatre (teatro)	February (febrero)
Horseman (jinete)	Model (modelo)	Paint (pintura)
Bronze (bronce)	Path (camino)	Similar (similar)
Cardboard (cartón)	Morning (mañana)	Message (mensaje)
Shoe (zapato)	Mountain (montaña)	Next (próximo)
Light (ligero)	Approach (acercar)	Liquid (líquido)

Note: Original Spanish Words in parenthesis.