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Foveal vs. Parafoveal Processing in Anxiety: Broadened Spatial Attention for Threat Words

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We investigated the processing of threat-related, positive, and neutral words in parafoveal and in foveal vision as a function of individual differences in trait anxiety. In a lexical-decision task, word primes were presented for 150 ms either parafoveally (2.2° away from fixation; Experiment 1) or foveally (at fixation; Experiment 3) followed by a probe word; or a foveal probe word was presented alone (with no prime; Experiment 2). Results showed that parafoveal prime threat words facilitated responses to probe threat words for high-anxiety individuals, in comparison with neutral and positive words, and relative to low-anxiety individuals. In contrast, when the words were presented foveally, there were no differences in resting activation level (i.e., accessibility to single word meanings) or firing thresholds (i.e., foveal priming) as a function of emotional content and anxiety. This reveals a covert attention bias towards threat stimuli in anxiety.

Considerable research has been concerned with the processing of threat-related stimuli by individuals varying in trait anxiety. Many theorists (Eysenck, Derakshan, Santos, & Calvo, 2007; Fox & Georgiou, 2005; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007) have assumed that individuals high in trait anxiety have facilitated processing of threat-related stimuli compared to those low in trait anxiety. People high in anxiety would be characterized by hypervigilance (i.e., alertness and selective orienting) to threat-related stimuli, with hypervigilance being functional in facilitating early threat detection and producing prompt anticipatory defensive responses to avoid harm. It must, nevertheless, be

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noted that, in some studies, trait anxiety has been found to be associated with a deficient inhibitory control of attention to distracting information (as proposed by the Attentional Control Theory developed by Eysenck et al., 2007) rather (or more) than with enhanced attentional alertness and orienting to threat-related information, which would be associated more with high state anxiety than with high trait anxiety (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010; Pacheco-Unguetti, Lupiáñez, & Acosta, 2009).

In the current study we focused on the alertness/orienting or hypervigilance conceptualization. To address this issue, we investigated a mechanism involving the broadening of attentional span for threat-related words presented parafoveally (i.e., away from fixation) at the same time as a non-threat word at fixation. Threat words are assumed to activate *alertness*, due to their being signals of danger or harm. In addition, the presentation of the words eccentrically in the visual field—concurrently with centrally presented words—would allow for selective *orienting* to take place. Such an attentional span broadening mechanism would permit eccentric threat stimuli to be processed outside the focus of overt attention, i.e., when they appear at extrafoveal locations. An eye fixation encompasses a high-acuity foveal vision area of about 2° (Wandell, 1995). Beyond the foveal eye-fixation boundaries, parafoveal processing occurs outside the focus of overt attention. Overt visual attention involves eye fixations on stimuli whereas covert visual attention does not (see Findlay & Gilchrist, 2003). Of central interest in the experiments to be reported here is to compare the effects of anxiety on foveal and parafoveal processing of threat-related stimuli.

This issue is important at a theoretical level, where there is controversy concerning the effects of anxiety on the breadth of attention. Easterbrook (1959; see also Staal, 2004) claimed that anxiety produces attentional narrowing whereas Eysenck et al. (2007) argued that anxiety can produce a broadening of attention. These two theoretical positions differ with respect to the predicted effects of anxiety on parafoveal processing of threat-related stimuli by anxious individuals. According to Easterbrook's (1959) hypothesis, anxious individuals should exhibit less parafoveal processing than non-anxious ones because attention is narrowly focused on foveal stimuli. In contrast, Eysenck et al. (2007) predict more processing of parafoveal threat-related stimuli by anxious than by non-anxious people.

The hypothesis that anxiety could facilitate the processing of extrafoveal threat-related stimuli has been addressed in some prior studies. Fox (1993, 1994) adapted the emotional Stroop task, in which colour patches were presented concurrently with threat words spatially separated

(2.1°, Fox, 1993; or 2.5°, Fox, 1994) from the patch. The task was to name the patch colour as rapidly as possible. Fox (1993) found that high-anxious participants exhibited interference with colour naming when threat words were presented parafoveally, but Fox (1994) did not. Fox, Russo, Bowles, and Dutton (2001) used a cuing paradigm, in which cue words were presented for 100 ms on the opposite side from a target that had to be located (the separation between the fixation point and the cue word was more than 3°). Participants took longer to localize the target when the cue was a threat word than when it was a positive or a neutral word. This indicates parafoveal capture of attention by the threat words, but the low- and high-anxious groups did not differ in terms of interference. Accordingly, there is no conclusive evidence for the threat processing of stimuli outside of overt attention in anxiety.

Following the work of Fox and her collaborators, more recently, Calvo and Eysenck (2008) used a lexical-decision paradigm in which prime words were presented parafoveally (displaced 2.2° to the right or left of fixation) and briefly (150 ms), followed by a probe word (or non-word). Importantly, a gaze-contingent foveal-masking technique was employed, i.e., the parafoveal prime word was masked if viewers moved their gaze towards it. So the prime word could be processed in parafoveal vision but could not be foveally fixated. Parafoveal prime threat words facilitated lexical-decision responses to probe threat words for participants high in trait anxiety, in comparison with neutral and positive words, and relative to low-anxiety participants. This reveals an advantage in threat processing by covert attention. Nevertheless, Calvo and Eysenck (2008) investigated parafoveal priming specifically and did not include a foveal condition, and therefore a comparison between covert and overt attention could not be made.

The aim of the current study was to test the hypothesis that there is a broadening of attentional span for threat-related words outside the focus of overt attention in high trait-anxiety individuals. To this end, we presented threat, positive, or neutral words in either parafoveal (available to covert attention) or foveal (available to overt attention) vision to low and high anxiety participants. In a lexical-decision task, participants decided as rapidly as possible whether a probe letter string formed (or did not form) a meaningful word. The probe word (or nonword) was preceded by a parafoveal prime word (Experiment 1), no prime (Experiment 2), or a foveal (i.e., centrally presented, at fixation) prime word (Experiment 3). In a repetition-priming paradigm, the prime words were either identical or unrelated in meaning to the probe. If the prime word is perceived, there will be faster responses to a probe when the prime is identical than when it is unrelated (if the prime is not perceived, there will be no facilitation of the identical probe, relative to the unrelated prime-probe condition). Most importantly, if threat-related words are preferentially processed, the priming effect will be stronger for them than for the other word categories, and especially for high-anxiety participants.

EXPERIMENT 1

Parafoveal Processing of Words

Parafoveal prime words (threat-related, positive, or neutral) were presented for 150 ms, concurrently with a neutral foveal word. Under these conditions, it is highly unlikely that the parafoveal prime is overtly attended to, as revealed by the absence of fixations on the prime words in the Calvo and Eysenck (2008) eye-movement studies (using comparable spatial and temporal parameters), thus being available only to covert attention. Following the prime display, a central string of letters appeared as a probe for lexical decision. If there is broadened attentional span for threat words in high-anxiety individuals, these (but not those low in anxiety) will show positive priming for such words (but not for the other word categories) when presented parafoveally as primes.

Experiment 1 allowed us to go beyond a mere replication of the Calvo and Eysenck (2008) study, and to examine attentional bias, i.e., *selective* attention to threat-related stimuli that appear *simultaneously with* neutral stimuli, as a function of anxiety. Attentional bias could not be examined in Calvo and Eysenck (2008) because a meaningless string of xx+xx (instead of a word) appeared foveally at the same time as the parafoveal word. The neutral-emotional word presentation in Experiment 1 is similar to the well-known dot-probe paradigm that has often been used to investigate attentional bias (see Bar-Haim et al., 2007). In dot-probe studies, also two words appear simultaneously, away from a central fixation point, and thus attentional bias suggests that threat content might be initially processed extrafoveally. However, first, the visual angle of the word location has not generally been defined with precision in dot-probe studies. This makes it difficult to determine whether the word stimuli remained in truly parafoveal vision. Second, in dot-probe studies, the words were typically presented for 500 ms, which exceeds minimal saccade latency and therefore permits fixations on the words. Thus, such studies have not separated overt from covert attentional bias. In our Experiment 1, the temporal (150-ms prime display) and spatial (2.2° of visual angle) parameters allowed us to examine whether threat words are preferentially processed by covert attention.

METHOD

Participants. Twenty-four psychology undergraduates high in trait anxiety (19 female) and 24 low in trait anxiety (19 female) participated for course credit. They were selected from a group of 88 students, as a function of their scores in the trait scale of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1982). Those students with the highest (M = 53.7; SD = 4.6; 77th percentile) or the lowest (M = 36.7; SD = 4.4; 23rd percentile) STAI-trait scores (range: 20-80) were selected as high- or low-anxiety participants, respectively, $t(46) = 16.12$, $p < .0001$.

Stimuli. We used 48 words in each of three categories of *target* words (threat-related: e.g., *cancer* or *murder*; positive: e.g., *caress* or *happy*; and neutral: e.g., *cable* or *bridge*; see Appendix), which were comparable in word length (M = 6.08 letters in each category; there were 12 five-letter words, 20 six-letter words, and 16 seven-letter words) and lexical frequency (threat: M = 36.96 occurrences per million; positive: 36.88; neutral: 36.96), as assessed by B-Pal (Davis & Perea, 2005). We selected and classified the words a priori into each emotional valence category, but then an additional group of 20 participants (see Calvo et al., 2006) validated this in a rating task. Threat and neutral words had mean ratings of, respectively, –2.10 (SD = 0.78) and +0.08 (SD = 0.61) on a scale of –3 (very negative) to +3 (very positive), $t(94) = 15.29$, p < .0001. The positive words had mean valence ratings of +1.94 (SD = 0.81), and were significantly different from the neutral words, $t(94) = 12.65$, p < .0001. These 144 target words were presented as *probes*, and also as *parafoveal primes* in the prime-probe *identical* condition (see Design). There were also 144 neutral words serving as *parafoveal primes* in the prime-probe *unrelated* condition. An additional (filler) 192 neutral words appeared foveally at the same time as the parafoveal primes, to produce competition for attentional resources and to make the foveal location task-relevant. Finally, 48 nonword probe stimuli (i.e., one letter of a valid word was changed) were also used.

Apparatus and procedure. Participants were presented with sequences of stimuli on a 17-inch screen, at a 59-cm viewing distance, using a chin and forehead rest. They were instructed to maintain central gaze fixation, as the lexical-decision task would have to be performed on centrally presented probes. Thus, the central location (where the distracter appeared immediately before the probe) was task-relevant, whereas the parafoveal location was task-irrelevant (and therefore parafoveal primes were assumed to be ignored). Each stimulus sequence (see Figure 1) consisted of (a) a central cross, (b) two prime words (150 ms), one at foveal fixation and the other in parafoveal vision, with its center displaced 2.2° from central fixation, either to the right or to the left visual field; (c) a dark screen interval (150 ms); (d) a central string of letters (word or nonword) serving as the probe; and (e) verbal feedback following the participant's response. Participants responded to the probe by pressing one of two keys for "word" and "nonword".

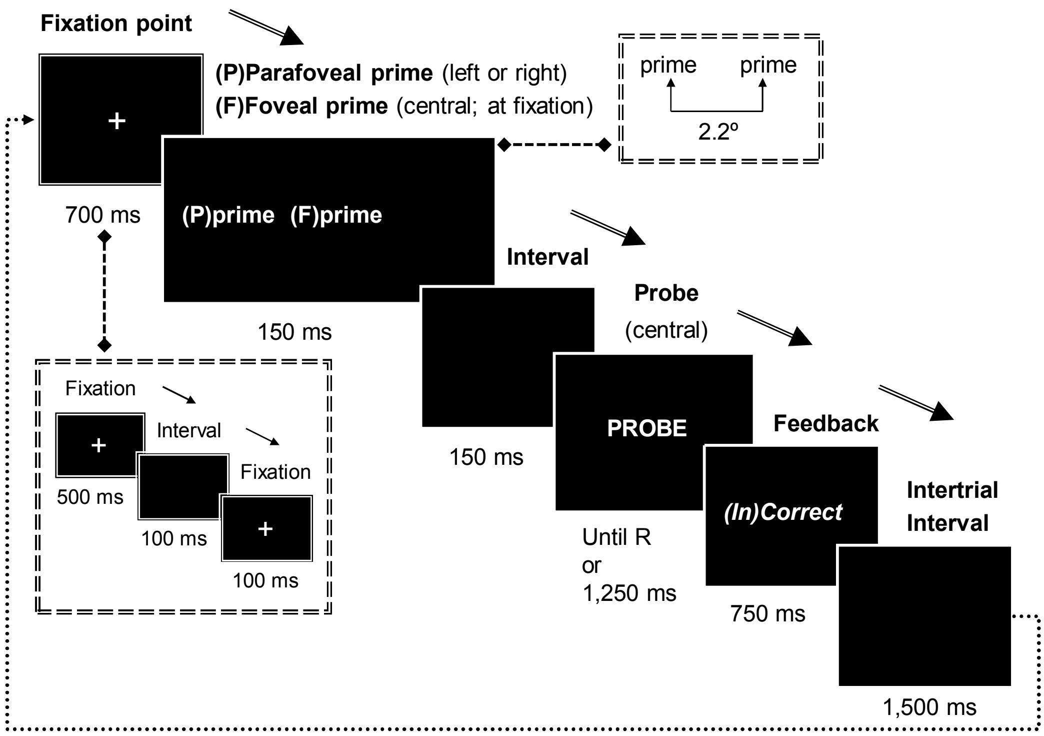

Figure 1. Sequence of events on each trial in Experiment 1. (P)prime: parafoveal prime. (F)prime: foveal prime.

Design. A mixed factorial design involved Trait Anxiety (low vs. high) as a between-subjects factor, and Valence of the probe (threat vs. positive vs. neutral), prime-probe Relatedness (identical vs. unrelated), and Visual Field of the parafoveal prime (left vs. right), as within-subjects factors. For each participant, 230 trials were presented (192 involving probe words and 48 involving nonwords). According to the manipulation of the prime-probe relatedness factor, we therefore used a repetition-priming, rather than a semantic-priming paradigm.

RESULTS

Mean accuracy and reaction times for correct responses to probes (see Table 1) were analyzed in an Anxiety (high vs. low) × probe Valence (threat vs. neutral vs. positive) × prime-probe Relatedness (identical vs. unrelated) × Visual Field (left vs. right) ANOVA. There were no significant effects on response accuracy (M = 97.0%). In contrast, for reaction times, an effect of relatedness, $F(1, 46) = 8.58$, $p < .01$, indicated that lexical-decision responses were faster in the identical (M = 630 ms) than in the unrelated condition (M = 644 ms). This effect was qualified by a relatedness by visual field interaction, $F(1, 46) = 5.85$, $p < .025$, with the relatedness effect being significant in the right (M identical = 623 ms vs. M unrelated = 648 ms; $t(47) = 3.90$, $p < .0001$), but not in the left (637 vs. 639 ms) visual field.

A three-way Anxiety by Valence by Relatedness interaction (see Figure 2), $F(2, 92) = 3.30$, $p < .05$, was further analyzed by planned contrasts. Importantly, for high-anxiety participants, responses to threat words were faster in the identical than in the unrelated condition (637 vs. 670 ms), $t(23) = 3.92$, $p < .001$; differences were nonsignificant for neutral (650 vs. 664 ms) and positive (630 vs. 632 ms) words. In contrast, for low-anxiety participants, differences did not reach statistical significance for either threat (624 vs. 619 ms), neutral (624 vs. 640 ms), or positive (616 vs. 636 ms) words.

DISCUSSION

A priming effect on lexical-decision latencies revealed faster responses when the probe word was preceded by an identical than by an unrelated parafoveal prime, with such priming effect occurring specifically in the right visual field (RVF). This indicates that RVF parafoveal words were processed. This RVF lateralization advantage in word recognition has also been frequently found in prior priming studies using the divided visual field technique (e.g., Kanne, 2002), and single word (rather than prime-target pairs) detection paradigms (e.g., Hyönä & Koivisto, 2006). There are two major explanations for this RVF superiority. First, a left-hemisphere dominance of the brain for visual word recognition has been proposed, due to the left hemisphere relying more on covert attention, and the right hemisphere being more dependent on overt attention (e.g., Lindell, Arend, Ward, Norton, & Wathan, 2007). Second, there is an asymmetry of perceptual span in reading, which extends more to the right than to the left of fixation, linked with rightward reading habits rather than with an innate superiority for word recognition in the RVF (e.g., Battista & Kalloniatis, 2002). It is, nevertheless, possible that reading habits and hemispheric dominance are complementary rather than incompatible: The contribution of brain specialisation mechanisms in the LH could be magnified due to reading habits. An extensive review and discussion of the RVF advantage in word recognition has been addressed in Calvo and Nummenmaa (2009) and Lindell (2006).

Table 1. Mean Lexical Decision Times (in ms; and SDs in parenthesis) for Probe Words, as a Function of Probe Valence, Prime-Probe Relatedness, and Prime Visual Field, in the Low and the High Trait Anxiety Groups, in Experiment 1.

	Parafoveal Prime					
Probe	Left Visual Field			Right Visual Field		
Valence	Identical	Unrelated	U-I	Identical	Unrelated	U-I
LOW TRAIT ANXIETY						
Threat	628 (97)	624 (85)	-4	621 (73)	615 (72)	-6
Neutral	642 (96)	642 (76)	0	606 (85)	637 (90)	31
Positive	611 (79)	624 (97)	13	621 (83)	649 (104)	28
HIGH TRAIT ANXIETY						
Threat	655 (96)	663 (101)	8	619 (91)	676 (97)	57
Neutral	657 (102)	656 (100)	-1	643 (95)	673 (93)	30
Positive	631 (109)	624 (95)	-7	628 (88)	640 (104)	12

U-I: difference Unrelated-Identical (i.e., activation or positive priming scores). Positive scores indicate positive priming (i.e., facilitation) in the identical prime-probe condition; negative scores show inhibition.

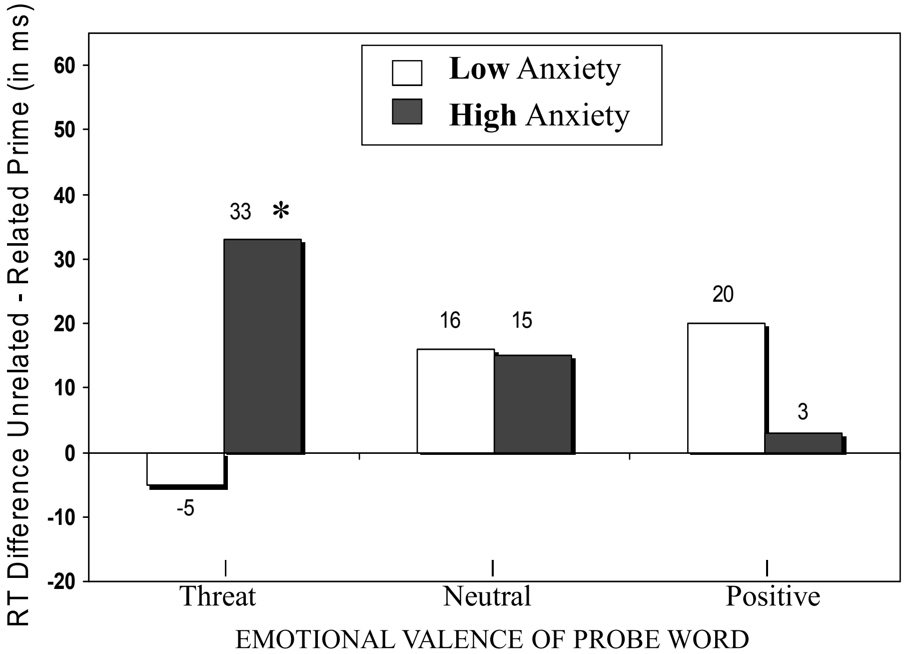

Figure 2. Activation scores (i.e., lexical-decision times for the probe in the unrelated condition minus RTs in the identical condition) as a function of emotional valence of probe word and trait anxiety, in Experiment 1. Positive scores indicate positive priming (i.e., facilitation). Asterisks show significant differences.

The most important finding in relation to the specific aims of this study was the anxiety by valence by relatedness interaction, with enhanced parafoveal priming for threat words in the high-trait-anxious group. This result resembles the one reported by Calvo, Castillo, and Fuentes (2006) when emotional state, rather than trait, was considered. These authors found parafoveal priming for threat words in lexical decision when pre-exposure to negative visual scenes had induced an emotional state of anxiety or sadness in participants not selected as a function of trait anxiety. In general, these results are consistent with emotion-congruent processing theories (see Rusting, 1998): A negative trait or mood state would make aversive representations in memory more accessible, which in turn would lower the threshold level for perception of parafoveal threat words. At a more specific level, and assuming there were no fixations on the parafoveal prime words (as was confirmed by Calvo and Eysenk, 2008, using an eyetracking methodology), these findings are consistent with the hypothesis of a covert attentional bias, i.e., selective processing of threat stimuli—presented concurrently with neutral stimuli—outside the focus of overt attention. That is, the parafoveal priming effects suggest that attentional span, or the functional field of view, is broadened by anxiety (trait or state) for threat-related words (see General Discussion).

Experiment 1 represented the main approach to address the issue of the attentional span broadening mechanism, given that the prime words were presented *outside* the focus of overt attention, and therefore some kind of attentional broadening was required to process them. In Experiments 2 and 3, we used a complementary approach to address this issue, by presenting the word stimuli *under* the focus of overt attention, thus without the need of any attentional broadening to process the words. This allowed us to examine, and eventually rule out, alternatives to the attentional broadening hypothesis.

EXPERIMENT 2

Foveal Lexical Access

In Experiment 2 we investigated an alternative hypothesis to account for the parafoveal processing of threat words in high-anxiety individuals. According to the *lexical-access-speed* hypothesis, it is possible that threat words are highly accessible in the mental lexicon of high-anxiety individuals, regardless of any priming. This would make these people more sensitive to detect any external cue that matches (or is congruent with) the content of their accessible memories, regardless of stimulus location. If threat words are highly accessible, lexical-decision latencies for *single* threat words should be especially fast in high-anxiety participants. To test this prediction, each word was presented individually, with no prime, at fixation (i.e., foveally), in a lexical-decision task. In these conditions, no broadenening of attentional span was necessary, as the word stimuli were directly available to overt attention.

METHOD

Participants. Twenty (15 female) psychology undergraduates high in trait anxiety and 20 (15 female) low in trait anxiety participated in this experiment. They were selected from a group of 92 students. STAI (Spielberger et al., 1982) trait-anxiety scores were different (ts > 15, p <

.0001) for the high-anxiety (*M* = 53.1; 78th percentile) and the low-anxiety (*M* = 32.1; 22nd percentile) groups.

Apparatus and materials, design and procedure. The same apparatus and target words as in Experiment 1 were used. The design involved Trait Anxiety (low vs. high) as a between-subjects factor, and probe word Valence (threat vs. neutral vs. positive), as a within-subjects factor. One word (or nonword) was presented as a probe on each trial in a lexical-decision task, with no prime. The probe word was preceded by a 500-ms cross at fixation, which was replaced by the word at the same central location of the screen. There were 144 trials with probe words (48 of each valence) and 48 nonword trials.

RESULTS

Errors and mean correct reaction times in the lexical-decision task were analyzed in a 2 (trait anxiety) by 3 (word valence) ANOVA. There were no significant effects on response accuracy (*M* = 98.1%). For lexical-decision latencies, only a nonsignificant trend appeared for the main effect of valence, $F(2, 76) = 2.42$, $p = .095$ (ps $\geq .15$, after Bonferroni corrections). Importantly, the effects of anxiety and the interaction were nonsignificant (both Fs < 1). Mean latencies are shown in Table 2. In addition, Pearson correlation analyses were conducted between psycholinguistic variables and word recognition performance. Lexical-decision times were significantly correlated with word length, $r(144) = .36$, $p < .0001$, and lexical frequency, $r(144) = -.43$, $p < .0001$, with latencies being longer as word length increased and as frequency decreased.

Table 2. Mean Lexical Decision Times (in ms; and SDs in parenthesis) for Probe Words, as a function of Probe Valence and Trait Anxiety, in Experiment 2.

Probe	Low-Anxiety Group	High-Anxiety Group
Valence	No Prime	No Prime
Threat	639 (85)	636 (72)
Neutral	632 (81)	633 (79)
Positive	626 (72)	631 (77)

DISCUSSION

Results revealed an absence of differences between low- and high-anxiety groups and no interaction with word valence. The failure to find any differences cannot be attributed to insensitivity or inaccuracy of the dependent measures, as there were significant correlations in the expected direction (Balota, Cortese, Sergent-Marshal, Spieler, & Yap, 2004) between psycholinguistic variables and lexical-access performance. Rather, the findings reveal that low- and high-anxious groups do not differ in the resting activation level of threat words in their mental lexicon. The lack of any advantage in the processing of threat words by high-anxiety individuals when the word stimuli were presented at fixation—and therefore directly available to overt attention and with no need of attentional broadening—is thus contrary to the lexical-access hypothesis, as an alternative explanation of the parafoveal priming advantage for threat words in high-anxiety individuals.

EXPERIMENT 3

Foveal Priming

In Experiment 3 we investigated another alternative hypothesis—that would not involve an attentional broadening mechanism—to account for the parafoveal processing of threat words in high-anxiety individuals. According to the alternative, *readiness-for-activation* hypothesis, it is possible that threat words are more likely to be activated by a prime than other words are, regardless of prime location. If readiness of activation of threat-word representations is responsible for the parafoveal priming effects, lexical decisions for *foveally primed* threat words should be especially fast in high-anxiety participants. To examine this account in Experiment 3, the probe word was preceded by a prime word presented at fixation. In these conditions (as was the case for Experiment 2), no broadenening of attentional span was necessary, as the word stimuli were directly available to overt attention (unlike in Experiment 1, where the prime word appeared outside the focus of attention)[1] A difference between

[1] A reviewer of this article suggested an alternative for Experiment 3, involving the presentation of the foveal prime words (threat, neutral, or positive) concurrently with a parafoveal neutral distracter. This would make Experiments 1 and 3 more strictly comparable, with two words presented simultaneously. However, neutral words have proved to be perceived parafoveally in the right visual field (with priming scores of 30-31 ms, as shown in Experiment 1), even in the presence of a concurrent foveal neutral word. Accordingly, such concurrent parafoveal distracters could produce interference with the processing of the foveal primes, and therefore mask or reduce the role of genuine foveal

the accessibility (Experiment 2) and the readiness-for-activation (Experiment 3) mechanisms is that the former implies higher *resting-activation levels* for threat words, while the latter implies lower *firing thresholds* when threat words are primed (see Allen, Smith, Lien, Grabbe, & Murphy, 2005).

METHOD

Participants. Twenty (15 female) psychology undergraduates high in trait anxiety and 20 (15 female) low in trait anxiety participated in this experiment. They were selected from a group of 92 students (different from those in Experiment 2). STAI (Spielberger et al., 1982) trait-anxiety scores were different (*t*s > 15, *p* < .0001) for the high-anxiety (*M* = 53.9; 79th percentile) and the low-anxiety (*M* = 31.6; 21st percentile) groups.

Apparatus and materials, design and procedure. The same apparatus and target words as in Experiment 1 were used. The design for Experiment 3 involved Trait Anxiety, Valence, and prime-probe Relatedness (same vs. unrelated; within-subjects). After a 500-ms cross in the center of the screen, a prime word appeared also at fixation for 150-ms, followed by a 150-ms blank interval, and then the probe word on the same location. So the important difference between Experiments 1 and 3 is that in the former the prime appeared extrafoveally, whereas in the latter it appeared at fixation, before the probe; and the important difference between Experiments 2 and 3 is that no prime appeared in the former (just the probe), whereas it was presented in the latter, before the probe.

RESULTS

The 2 (trait anxiety) × 3 (word valence) × 2 (prime-probe relatedness) ANOVA yielded main effects of relatedness on response accuracy (*M* = 96.9%), $F(1, 38) = 17.04$, $p < .0001$, and latencies, $F(1, 38) = 674.72$, $p < .0001$. There were more correct responses and shorter latencies for probes in the identical condition (*M* = 98.9% and 561 ms) than in the unrelated condition (*M* = 95.0% and 705 ms). Importantly, all the statistical effects involving anxiety were nonsignificant (all *F*s < 1). Mean latencies are shown in Table 3. In addition, lexical-decision times were significantly

priming. Given that with Experiment 3 we aimed to determine the *pure* effects of the primes when they were under the focus of overt attention, we think the current display conditions (only one foveal prime, with no concurrent parafoveal distracter) allow for a better estimate of such effects.

correlated with word length, $r(144) = .28$, $p < .001$, and lexical frequency, $r(144) = -.42$ $p < .0001$, with latencies being longer as word length increased and as frequency decreased.

Table 3. Mean Lexical Decision Times (in ms; and SDs in parenthesis) for Probe Words, as a function of Probe Valence, Trait Anxiety, and Prime-Probe Relatedness, in Experiment 3.

Probe	Low-Anxiety Group			High-Anxiety Group		
Valence	Identical	Unrelated	U-I	Identical	Unrelated	U-I
Threat	575 (99)	719 (108)	144	554 (81)	699 (89)	145
Neutral	569 (99)	716 (106)	147	558 (89)	696 (80)	138
Positive	559 (105)	709 (99)	150	553 (83)	692 (74)	139

U-I: difference Unrelated-Identical (i.e., activation or positive priming scores). Positive scores indicate positive priming (i.e., facilitation) in the identical prime-probe condition; negative scores show inhibition.

DISCUSSION

There were no differences between low- and high-anxiety groups in foveal priming and no anxiety by valence interaction. This cannot be attributed to insensitivity or inaccuracy of the dependent measures, as, first, there were strong effects of relatedness, thus showing that foveal priming occurred; and, second, there were significant correlations in the expected direction between psycholinguistic variables and performance on foveal priming (see Balota et al., 2004). These findings reveal that threat words in the mental lexicons of high-anxious individuals are not more readily activated by a word prime than those of low-anxious ones. Thus they rule out the readiness-of-activation hypothesis as an alternative explanation of the parafoveal priming advantage for threat words in high-anxiety individuals. Furthermore, indirectly, this is consistent with the hypothesis that an attentional span broadening mechanism is involved when the words appear outside the focus of overt attention. In other words, only when attentional broadening is necessary, due to the prime words being presented extrafoveally, does the anxiety/threat priming advantage appears.

GENERAL DISCUSSION

We investigated whether anxiety is associated with enhanced processing of threat-related words outside of overt attention, in comparison when words are presented at fixation. Results from Experiment 1 showed selective parafoveal priming, with facilitation in lexical decisions for primed threat words in high-anxiety participants. This suggests that threat words are more likely to be perceived than neutral words and positive words outside the focus of attention. These findings replicate those of Calvo and Eysenck (2008) with a different procedure. In the current study, the parafoveal prime word was presented concurrently with a foveal prime word, whereas in Calvo and Eysenck (2008) no foveal word (only a meaningless string of xx+xx) was presented at the same time as the parafoveal word. In spite of the greater competition for processing resources in the current experiment, there was also parafoveal anxiety-threat priming. This suggests that the effect is reliable and survives potential interference due to concurrent neutral information.

In contrast, results from Experiments 2 and 3 indicated that no such threat processing advantage occurred when words were presented foveally and thus were available to overt attention. These results are relevant to rule out the involvement of two cognitive mechanisms in the special priming for parafoveal threat words in high-anxiety individuals. Facilitated word recognition can be due to some words having high resting-activation levels and/or low firing thresholds, according to word recognition models (see Allen et al., 2005). However, this explanation does not account for the parafoveal threat/anxiety advantage, as accessibility and foveal priming were similar for threat words and the other word categories in high- and low-anxiety groups. Thus, the priming advantage for threat words in covert attention occurred in the absence of differences in the resting-activation or the firing mechanisms in overt attention. This lack of accessibility or foveal priming differences in lexical-decision tasks when words were presented singly at fixation have already been reported by MaLeod and Mathews (1991) and Bradley, Mogg, and Williams (1994). We have made a contribution by presenting the *same* words under parafoveal and foveal conditions, and showing that anxiety facilitates processing of threat words in the former but not in the latter condition. Thus the enhanced covert attention to threat words is a genuine and a special effect.

The covert attention to threat stimuli is consistent with the notion that anxious individuals are hypervigilant. Hypervigilance can be achieved by a mechanism involving the lowering of perceptual thresholds, to increase the sensitivity for low-intensity stimuli, as evidenced by research on subliminal presentation (Mayer, & Merkelbach, 1999); or it can be achieved by a mechanism involving the broadening of attentional span, to favor the intake of eccentric threat-related information in the visual field, as revealed by the findings in the current study. We are assuming that anxiety can increase the spatial span of attention or functional field of view. Although this assumption has received some empirical support (Keogh & French, 1999; Shapiro & Lim, 1989), there is also theoretical controversy about it. In a classic theory that continues to have acceptance (see Staal, 2004), Easterbrook (1959) claimed that anxiety and related forms of negative arousal produce attentional narrowing. The finding that high trait anxiety is associated with parafoveal priming of threat words is inconsistent with Easterbrook's theory, according to which *low*-anxious individuals should show *more* evidence of parafoveal processing than high-anxious ones. In contrast, our findings are favourable to the hypothesis that anxiety can broaden of attention due to sensitivity to threat-related stimuli (see Eysenck et al., 2007)[2].

Why is there a special advantage in parafoveal but not in foveal threat processing as a function of anxiety? A potential explanation is that anxiety facilitates threat processing when priorities must be assigned to simultaneous (and therefore competing for resources) threat and neutral words, but not when single words are presented (MacLeod & Mathews, 1991). This explanation could indeed be applicable to the current study, where *two* prime words were presented in the parafoveal condition (Experiment 1) whereas only one word appeared in foveal conditions (Experiments 2 and 3). However, parafoveal priming occurred also in the Calvo and Eysenck (2008) study, even though only *one* (i.e., the parafoveal) word appeared at a time. Accordingly, there must be an additional explanation that applies specifically to covert attention processing, regardless of stimulus competition. Presumably, the enhanced sensitivity of

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[2] Positive emotions have been proposed to broaden the scope of attention, whereas negative emotions would produce narrowing (Fredrickson & Branigan, 2005; Gasper & Clore, 2002; see Clore & Huntsinger, 2007, for a review). At first sight, we might think that our findings are not consistent with this view, for which high anxiety should be associated with a narrowed (rather than broadened) attentional span. It must, however, be noted that, first, in those studies, broadening and narrowing were conceptualized in a general sense encompassing a wide range cognitive processes. Attentional span was not strictly defined in terms of the functional field of view, with no manipulation of stimulus eccentricity. Second, in those studies, emotional state or mood was manipulated, but no trait anxiety differences were considered and the stimulus affective content was not varied. Accordingly, it is difficult to make a comparison with the current study, in which we have found a broadening of the functional field of view specifically for threat-related stimuli in high-anxiety individuals.

high-anxiety individuals to threat words is of importance only when there is reduced stimulus evidence. The facilitatory role of anxiety manifests itself when a broadened attentional span is required. In Experiments 2 and 3, the words were displayed at fixation with no spatial constraints. In contrast, in both parafoveal conditions (Experiment 1, current study; and Calvo & Eysenck, 2008), there were spatial (i.e., visual acuity) limitations. In these conditions, a broadened attentional span for threat words would compensate for the reduced stimulus evidence and thus make high-anxiety individuals more likely to perceive the words for which they are especially hypervigilant, i.e., threat words.

To account for the facilitated access to the cognitive system of threat-related words outside the spatial focus of attention, Calvo et al. (2006) proposed a mechanism in accordance with models of automatic emotional processing (e.g., Robinson, 1998). This mechanism would proceed unconsciously, involuntarily, in parallel to other processes, and without or prior to attention. This might seem inconsistent with the view defended here that the facilitated access of parafoveal threat words is due to broadened attentional span. Is then *attention involved or not* in our parafoveal priming effects? Lachter, Forster, and Ruthruff (2004) strongly argued that there is no word recognition without attention. The distinction between covert and overt attention seems critical to decide about this issue. Overt attention relies on eye fixations on the stimuli, whereas covert attention involves neural adjustments without eye movements (Wu & Remington, 2003). Furthermore, covert shifts are thought to be faster (50 to 100 ms) than overt saccades (150 ms; see Lachter et al., 2004; and Rayner, 1998). Calvo and Castillo (2009) showed that, although word recognition may need covert attention (as claimed by Lachter et al., 2004), recognition can occur in the absence of overt attention. Accordingly, the current parafoveal prime presentation (at a task-irrelevant location, for 150 ms, and with a concurrent foveal word) prevented overt attention while allowing covert attention. The parafoveal priming effects were automatic in the sense that they occurred without overt attention (and involuntarily, and in parallel, and probably unconsciously). The broadening of attentional span presumably affected the neural mechanism controlling covert attention in the visual periphery (e.g., the magnocellular layers), but not overt attention. Therefore, both the automaticity hypothesis and the attentional broadening hypothesis are compatible and complementary. Nevertheless, in a further refinement of this issue, an experiment could be conducted in which the parafoveal prime words would be presented for 50 ms and backwardly masked, thus preventing also covert attention.

In conclusion, high-anxious individuals have privileged access to parafoveal threat-related words, relative to neutral or positive words. The priming superiority of threat words occurred even though they were of the same length and lexical frequency as the neutral and the positive words. In addition, this threat-anxiety processing superiority was not dependent on the threat words having higher resting-accessibility levels or lower activation thresholds. We propose that the spatial attention span of high-anxious individuals is broadened for threat-related words as part of a hypervigilance mechanism. Presumably, this mechanism is potentiated by a greater familiarity with threat words by anxious individuals (see Calvo & Eysenck, 2008). Familiarity would represent an advantage—due to increased sensitivity and lowered stimulus thresholds—for the recognition of these words in conditions with perceptual constraints.

RESUMEN

Procesamiento foveal vs. parafoveal en la ansiedad: Ampliación de la atención espacial para las palabras de amenaza. El presente estudio investiga el procesamiento parafoveal de palabras de amenaza, de contenido emocional positivo, y neutras, en función de diferencias individuales en rasgo de ansiedad. En una tarea de decision léxica, palabras estímulo (*prime*) fueron presentadas durante 150 ms parafovealmente (alejadas 2.2° del punto de fijación; Experimento 1) o fovealmente (en el punto de fijación; Experimento 3), seguidas por una palabra de prueba (*probe*), o bien las palabras *probe* fueron presentadas solas (sin *prime*; Experimento 2). Los resultados mostraron que las *prime* parafoveales de amenzaza facilitaron las respuestas a las *probe* de amenaza en los participantes con ansiedad elevada, en comparación con las palabras positivas y las neutras, y con los participantes con ansiedad baja. En contraste, cuando las *prime* fueron presentadas fovealmente, no se produjeron diferencias en los niveles básicos de activación de las *probe* aisladas (línea base de accesibilidad), ni tampoco en los umbrales de activación por el *prime*, en función del contenido emocional de las palabras o de la ansiedad de los participantes. Esto revela un sesgo en la atención encubierta a estímulos amenazantes en las personas con ansiedad elevada.

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APPENDIX

List of Words Used as Stimuli

THREAT WORDS	POSITIVE WORDS	NEUTRAL WORDS
Coffin (ataúd)	Cake (tarta)	Hat (gorro)
Hate (odiar)	Kiss (besar)	Add (sumar)
Fight (pelea)	Enjoy (gozar)	Bag (bolso)
Tumor (tumor)	Handsome (guapo)	Cable (cable)
Cruel (cruel)	Beautiful (bello)	Beard (barba)
Tomb (tumba)	Humor (humor)	Ear (oreja)
Bomb (bomba)	Win (ganar)	Poem (poema)
Kill (matar)	Health (salud)	Walk (andar)
Virus (virus)	Success (éxito)	Nose (nariz)
Die (morir)	Happy (feliz)	Look (mirar)
Pain (dolor)	Play (juego)	Letter (carta)
Fear (miedo)	Good (bueno)	Floor (suelo)
Lash (azotar)	Compliment (halago)	Smooth (alisar)
Viper (víbora)	Cheer up (animar)	Paintbrush (brocha)
Mugging (atraco)	Optimum (óptimo)	Cheque (cheque)
Beating (paliza)	Like (gustar)	Horseman (jinete)
Agony (agonía)	Pleasant (agrado)	Bronze (bronce)
Poison (veneno)	Praise (elogio)	Cardboard (cartón)
Thief (ladrón)	Merit (mérito)	Shoe (zapato)
Alarm (alarma)	Great (genial)	Light (ligero)
Panic (pánico)	Treasure (tesoro)	Bird (pájaro)
Cry (llanto)	Hug (abrazo)	Trial (ensayo)
Wound (herida)	Affection (afecto)	Moustache (bigote)
Crime (crimen)	Nice (bonito)	Shoulder (hombro)
Horror (horror)	Kind (amable)	Tent (tienda)
Suffer (sufrir)	Love (cariño)	Close (cerrar)
Terror (terror)	Helpful (ayudar)	Bridge (puente)
Jail (cárcel)	Gift (regalo)	Harbor (puerto)
Cancer (cáncer)	Prize (premio)	Theatre (teatro)
Fire! (¡fuego!)	Feast (fiesta)	Model (modelo)
Blood (sangre)	Pleasure (placer)	Path (camino)
War (Guerra)	Luck (suerte)	Morning (mañana)
Victim (víctima)	Delight (delicia)	Mountain (montaña)
Shoot (fusilar)	Admire (admirar)	Approach (acercar)
Rape (violada)	Applause (aplauso)	Bricklayer (albañil)
Suffocation (asfixia)	Caress (caricia)	Broom (cepillo)
Drowned (ahogado)	Erotic (erótico)	Keyboard (teclado)
Help! (Socorro)	Correct (acierto)	Form (impreso)
Malignant (maligno)	Wealth (riqueza)	Concrete (cemento)
Shot (disparo)	Champion (campeón)	Cotton (algodón)
Torture (tortura)	Talent (talento)	Track (sendero)
Stroke (infarto)	Lovely (hermoso)	Pavement (asfalto)
Murder (asesino)	Hope (ilusión)	February (febrero)
Punishment (castigo)	Friendship (amistad)	Paint (pintura)
Corpse (cadáver)	Triumph (triunfo)	Similar (similar)
Enemy (enemigo)	Fortune (fortuna)	Message (mensaje)
Ill (enfermo)	Joy (alegría)	Next (próximo)
Danger (peligro)	Smile (sonrisa)	Liquid (líquido)

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