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Research report

Valence-related vigilance biases in anxiety studied through event-related potentials

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Abstract

Introduction: Behavioral experiments on reaction time indicate that anxious subjects' vigilance-related attention is biased towards threatening words, though direct data on cerebral activity associated to this bias are conspicuously scarce. *Methods:* In the present study, event-related potentials (ERPs) were recorded from 30 subjects, grouped according to their scores in trait and state anxiety questionnaires. The specific role of the arousal and valence content of the stimulation in the vigilance bias was investigated by blocking the arousal content. Stimulation with high biological significance was employed. An S1 (sound)–S2 (emotional picture) task ensured that subjects were vigilant towards positive, negative or control (neutral) images. *Results:* Only subjects presenting high state scores and high state–trait combination scores showed significantly higher amplitudes in the Early Contingent Negative Variation during vigilance towards negative stimuli. This ERP component typically appears between S1 and S2 and reflects the intensity of vigilance. *Conclusions:* ERP activity detects cerebral indices that confirm the presence of valence-related vigilance biases in anxiety.

Keywords: Anxiety; Vigilance bias; Emotional valence; Event-related potentials; Early contingent negative variation

1. Introduction

Recent cognitive theories suggest that the vigilance bias towards threat stimulation is one of the critical factors that characterize anxiety (e.g., Eysenck, 1992; Mathews, 1990). These theories are based in part on findings obtained from behavioral experiments in which subjects scoring high in anxiety tests present clear indices of increased attention towards threatening words (e.g., Broadbent and Broadbent, 1988; MacLeod and Mathews, 1988; MacLeod and Rutherford, 1992; Mathews et al., 1996; Mogg et al., 1990; Richards and Millwood, 1989). An important idea present in many theoretical formulations on this subject is that the interaction of trait and state anxiety significantly influences the intensity of attentional biases (Williams et al., 1988; Mathews, 1990, 1993; Eysenck, 1992). In

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particular, the 'interaction theory' proposes that the intensity of vigilance bias towards threatening aspects of the environment is higher when the individual presents high state anxiety (or is under stress) together with high trait anxiety.

Vigilance-related attention is not the only aspect of attention that could present biases in anxious individuals. According to Posner and Petersen (1990), we can distinguish between "a general alert state and one in which attention is clearly oriented and engaged in processing information" (p. 33). Tasks or phases within a task in which a significant level of expectancy or alertness is necessary, such as those related to target detection, have been proposed to elicit, even before the target onset, the former type of attention (Posner and Petersen, 1990), often labeled, as in the present paper, 'vigilance'. On the other hand, recognition of visual material once it has been presented to subjects is associated with the second type of attention. While the vigilance-related bias towards threatening stimuli in anxiety has been clearly defined, it should be indicated that the direction of the biases hypothetically affecting those non-vigilance-related aspects or phases of attention occurring once the individual orients to the threatening stimulus remains unclear. Thus, it has been proposed that anxious individuals present an avoidance pattern following orientation to threat stimuli (Mathews, 1990; Mogg et al., 1987), but theoretical and experimental studies supporting the existence of a pattern of maintained attention towards negative stimulation also exist (Beck, 1976; Bower, 1981; Bradley et al., 1998). The present experiment focuses on vigilance-related attention, the aspect that seems best defined in cognitive theories, and that has received most experimental support.

Research on behavioral variables such as motor reaction time should be complemented by studies on brain electrical activity, since they can provide a "more complete picture of processing at various levels of the nervous system than can be obtained from behavioral methods alone" (Mangun and Hillyard, 1995, p. 43). It is indubitable that electroencephalographic (EEG) recording constitutes a more direct index of brain activity than behavioral data. Expectancy or vigilance (these two terms will by employed as synonyms hereafter) is usually studied in ERP research through the experimental paradigm employed to evoke the contingent negative variation (CNV). In its traditional form, this paradigm requires the presentation, in each trial, of a cue or warning signal (S1) and subsequently of a target or 'imperative' stimulus (S2) (Walter et al., 1964). The onset of S2 requires a rapid response from subjects (e.g., to press a button as rapidly as possible in order to terminate S2). During the interval between S1 and S2, in which the subject is vigilant, the CNV appears, terminating just after S2 onset. The CNV is actually composed by two subcomponents (see, e.g., the review by Rohrbaugh and Gaillard, 1983): the 'early' and the 'late' CNV. Early CNV is sometimes referred to as the 'CNV proper' (e.g., Basile et al., 1994), since it is more clearly related to vigilance or expectancy than late CNV. Particularly, early CNV amplitude relates *directly* to expectancy-related attention to S2 (e.g., see a review in McCallum, 1988). Thus, while late CNV, mainly reflecting preparation to respond to S2, is maximal at central–parietal locations, early CNV is mainly found over the frontal lobes, which involve attention-related areas (e.g., Basile et al., 1994; Leynes et al., 1998; Rohrbaugh and Gaillard, 1983).

Several studies have explored the relationship between CNV amplitude (though without distinguishing between its early and late subcomponents) and anxiety, both a positive correlation (Amabile et al., 1984; Proulx and Picton, 1984) and a negative correlation (McCallum and Walter, 1968; Low and Swift, 1971) being found. However, these studies did not manipulate the emotional content of the stimulation (S1 and S2 were neutral in all cases), so they do not provide relevant information on the issues we will explore in the present research. In fact, and to the best of our knowledge, experiments on biases in vigilance-related brain activity in anxious subjects have not been carried out up to now.

Two methodological issues regarding behavioral studies on attentional biases should be commented here. Firstly, affective words constitute the preferred stimulation in these studies, and it seems reasonable to complement their findings with those obtained through experiments using stimuli other than words. Indeed, the use of other types of stimuli would allow a wider generalization of findings. Moreover, the adaptive behavior that a preferential detection of threat supposes has evolved with respect to biologically-relevant stimuli whose emotional content, probably higher than that of words, needs to be explored in relation to vigilance biases in anxiety. Studies using pictorial, non-word stimuli confirm that this type of stimulation is more capable of eliciting attentional biases, since they trigger them even in individuals with moderate levels of anxiety (Bradley et al., 1998). The second methodological issue deals with the dimensions of emotion. The principal variance of the emotional meaning of stimulation has been proposed to be explained by two dimensions: the valence (negative–positive), and the arousal (calming–arousing) (Lang et al., 1993; Osgood et al., 1957; Russell, 1979). In relation to this, proposals exist indicating that anxious subjects attend preferentially not only to negative stimuli but to stimuli with high 'emotionality' (or high arousal, in the usual terminology on affective dimensions), both positive and negative ('emotionality hypothesis': e.g., Martin et al., 1991). Consequently, the main objective of the present experiment was to provide data on vigilance-related brain activity to a field in which this type of information is clearly useful but surprisingly scarce. Specifically, this study explored whether vigilance-related brain activity shows the presence, in anxious subjects, of valence-dependent biases by explicitly blocking the arousal content of pictorial, non-word stimulation with high negative and positive affective value. We hypothesize that early CNV will present higher amplitudes in anxious than in non-anxious individuals when a negative picture is announced by S1 (but not when a non-negative picture is announced).

2. Methods

2.1. Subjects

Thirty-six right-handed students from the Universidad Autónoma de Madrid took part in this experiment. They were selected from a sample of 220 subjects on the basis of their scores in the trait form of the State Trait Anxiety Inventory (STAI; Spielberger et al., 1988). Specifically, half of the 36 subjects presented scores over centile 75 and the other half under centile 25. The data from only 30 of them could eventually be analyzed, as explained later. These 30 subjects, 19 women (13 of them under centile 25 and 12 over centile 75) and 11 men (five under centile 25 and six over centile 75), were aged between 20 and 32 years (mean = 21.4, S.D. = 2.75). Four to 12 weeks after the date on which the trait form of the STAI test was filled out, subjects were cited for the EEG recording phase. Once in the laboratory, and just before this recording phase began, participants filled out the state form of the STAI. Two to 10 weeks after this recording phase, and in order to obtain additional data to more reliably establish the position of the subjects within the trait anxiety continuum through a different questionnaire from that previously employed, they filled out the Anxiety Situations and Responses Inventory (*Inventario de Situaciones y Respuestas de Ansiedad*; ISRA; Miguel and Cano, 1997), a specialized questionnaire for evaluating trait anxiety, and widely employed to evaluate this variable in Spanish samples. This test, which has 66 items, assesses issues related to cognitive, physiological and behavioral (motor) correlates of anxiety (correlation between scores obtained through the trait form of the STAI test and those obtained from ISRA were clearly significant: $r = 0.76$, $P < 0.001$). Thus, for analyses on brain activity, each subject's final level of trait anxiety was established as the average score from both STAI (trait form) and ISRA. Fig. 1 shows the distribution of the 30 subjects whose data were finally analyzed with respect to trait anxiety and with respect to state anxiety (defined by subjects' scores in the state form of STAI).

2.2. Stimuli

The experimental design followed an 'emotional variant' of the S1–S2 paradigm (Carretié et al., 2001). Cue (S1) stimuli consisted of three different tones (2900, 950 or 200 Hz). Each of these tones was found to be easily distinguishable from the rest in previous proofs. Meanwhile, target (S2) stimuli consisted of slides containing three color photographs: one at the top, the second in the middle

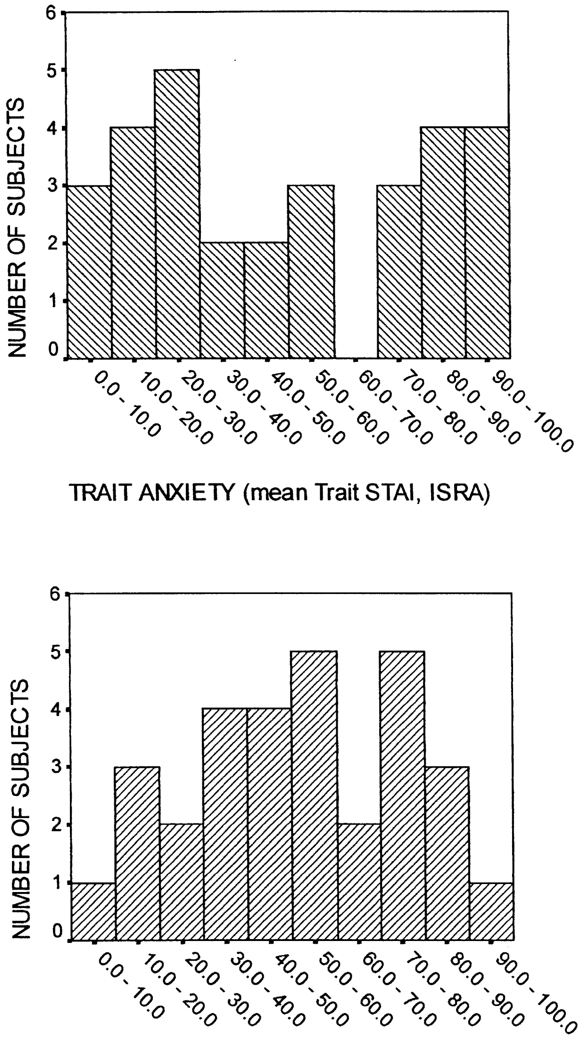

Fig. 1. Distribution of the subjects ($n=30$) with respect to their centile in trait anxiety (average of centiles obtained in the ISRA inventory and the trait form of the STAI inventory) and in state anxiety (state form of the STAI inventory).

and the third at the bottom of the slide (Fig. 2). One of the photographs or images showed an opposite sex nude (positive image), another showed a telephone (neutral), and the final one showed an orthopteroid insect (negative). They had a simple structure in which the motif appeared on a white background. Size and luminosity of the motifs were similar. These three images appeared in every target slide, and the only element differing from one target slide to another was the order in which these images were located (this order was counterbalanced in such a way that each image appeared the same number of times in the three possible locations within the target slide: top, middle or bottom). The 30 subjects whose data were finally analyzed completed a bidimensional scaling test for each type of image just after the recording sessions. This test assessed the valence (from -2, negative to 2, positive) and the arousal (-2, calming to 2, arousing) content of the pictures, two affective dimensions that are considered to explain, as indicated in the Introduction, the principal variance of the emotional meaning. Results from this test will be described later.

2.3. Recording

Nine locations (F3, Fz, F4, C3, Cz, C4, P3, Pz and P4) were used to record the ERPs using Ag/ClAg electrodes, the nosetip being the reference. Impedance was balanced and below 7 KΩ. High- and low-pass filters were set to 0.06 and 35 Hz, respectively, and the EEG was sampled at 100 Hz for 1625 ms (155 ms being prior to cue onset), corresponding to the interval between cue and target. Though subjects were instructed to continuously look at the center of the screen (marked with a dot), an EOG was recorded supra- and infra-orbitally at the left eye in order to control blink-related artifacts. Trials where EOG activity was greater than 40 μV were automatically rejected and repeated. Participants whose data were finally analyzed were those whose ocular artifact rate was less than 15% of trials (the recordings from four of the 36 subjects were eliminated for this reason).

2.4. Procedure

Participants were placed in an electrically and acoustically isolated room, and sat in a comfortable chair, 1 m from the screen. As already indicated, they were told to look continuously at a point located in the center of the screen. The slides were shown with a projector located in the apparatus room 1.20 m from a back-projection screen. The

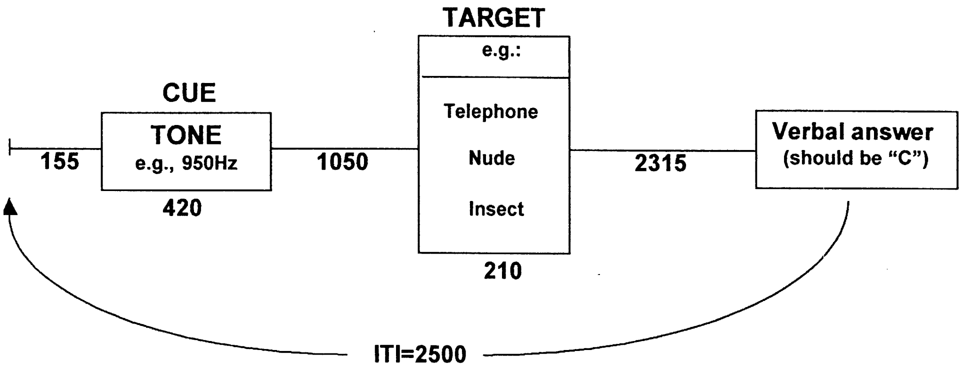

Fig. 2. Schematic representation of the experimental paradigm employed in the present experiment. An example of one of the possible cue/target combinations is included. ITI = Inter-trial interval.

center of the projection was at subjects' eye level. The resulting angle of vision was 10° with respect to the long, vertical side of the target slide, and 6.7° with respect to the horizontal side. As schematically illustrated in Fig. 2, cues were presented for 420 ms and, 1470 ms after their onset, target slides were presented for 210 ms.

Subjects were told that each of the three tones presented as cue (see Stimuli section) was a signal to detect one of the three images included in the target slide that appeared next. For one half of the subjects, the tone of 2900 Hz was associated with the positive image, that of 950 Hz with the neutral image and that of 200 Hz with the negative one. For the other half, the tone associated with the positive image was that of 200 Hz, the tone of 950 Hz went with the neutral image, and the tone of 2900 Hz went with the negative image. Participants were instructed to indicate the location (top, middle or bottom) of the image indicated by the cue by saying one of three possible letters (A, B and C, respectively). 2525 ms after target onset, a rising tone (clearly different from the simple cue sounds) indicated to subjects that they had to respond. Subjects were also instructed to blink only after this rising tone. Before the recording began, participants had the opportunity, guided by the experimenter, to hear all the tones and to identify their meaning, associating them with the targets. This 'familiarization' phase consisted of 12 training trials. A total of 102 cue–target trials was presented to subjects in the experimental phase, 34 for each category (positive, neutral and negative), and presentation order was random. Intertrial interval lasted 2500 ms.

Trials in which verbal responses were incorrect were eliminated, in order to discard those recordings associated with incorrect emotional categories. Recordings from two of the 36 subjects were eliminated because they committed more than 20% errors in at least one category of trials (positive, neutral or negative).

This design had several advantages for the present study. Firstly, target detection tasks ensure vigilance-related attention from subjects (Posner and Petersen, 1990). In this sense, this particular S1–S2 structure clearly places the vigilance phase of the task between cue and target, the CNV being elicited in that interval, so that the portion of the ERPs relevant for analyses is clearly pre-defined. The second advantage is related to the fact that the instructions given to participants did not explicitly establish that the experiment dealt with emotional reactions (the cue announced only in an implicit way the emotional category of the image to be detected). Specifically, this strategy helped to avoid a situation whereby participants considered that some of the stimuli were more important for the task than others (e.g., emotional stimuli more important than neutral ones), and thus to avoid a relevance-for-task effect, often described in previous studies (Carretié et al., 1997; Duncan-Johnson and Donchin, 1977: the stimuli on which the task focuses tend to elicit the highest amplitudes in certain endogenous ERP components). Moreover, homogenization of cognitive demands for all the stimuli makes it easier to reach more solid conclusions about the emotion-related causation of possible attentional differences.

3. Results

Four groups of analyses were carried out. First, some control analyses served to discard the possible effect of certain non-relevant variables. Second, certain operations on the recordings were necessary to more reliably analyze the experimental effects. Third, ERP components were detected and quantified. And fourth, statistical contrasts on the experimental effects themselves on these ERP components were computed.

3.1. Control analyses

As explained in the Methods section, each subject filled out a bidimensional scaling test for each picture after the recording sessions. This test assessed the valence and the arousal content of the three pictures presented in the target slides. First control analyses were analyses of variance (ANOVAs) on these assessments given by subjects to each picture in order to confirm, firstly, that their affective valence was that which was supposed a priori, and secondly, that positive and negative pictures were balanced with respect to their arousal. Table 1 shows the means and standard error of means of both dimensions for each type of image. One-way repeated-measures ANOVAs were computed for valence and for arousal dimensions, using Image type (three levels: Positive, Neutral, Negative) as factor. The Greenhouse—Geisser (GG) epsilon correction was applied to adjust the degrees of freedom of the F-ratios. Post-hoc comparisons were made to determine the significance of pairwise contrasts, using the Bonferroni procedure (alpha = 0.05). ANOVAs yielded significant differences both in valence and in arousal [$F(2,58) = 64.80$, GG epsilon = 0.99, $P < 0.001$ and $F(2,58) = 11.61$, GG epsilon = 0.92, $P < 0.001$, respectively]. Post-hoc contrasts indicated that Negative and Positive showed distinct valence but not distinct arousal. Positive and Negative differed from Neutral both in arousal and valence.

Table 1
Means and standard error of means (in parentheses) of valence (− 2, negative to + 2, positive) and arousal (− 2, calming to + 2, arousing) assessments given by the 30 subjects to the three types of pictures (neutral, positive and negative)

	Neutral	Positive	Negative
Arousal	− 0.133 (0.164)	0.633 (0.182)	0.800 (0.121)
Valence	0.533 (0.150)	1.400 (0.132)	− 1.067 (0.172)
Errors	3.200 (0.539)	2.567 (0.469)	2.767 (0.591)

Additionally, last row shows means and standard error of means (also in parentheses) of incorrect answers in the experimental task.

Secondly, differences with respect to the task difficulty associated with each category of trial (positive, neutral and negative; i.e., cue required the detection of the positive, neutral or negative image in the target slide, respectively) were analyzed, in order to ensure that the possible effects involving these categories were not due to this factor. The presence of differences may indicate that level of difficulty and, consequently, of attentional demand, is different for each trial category. Therefore, the number of errors in the task with respect to each type of trial was analyzed via a one-way repeated-measures ANOVA on factor Trial type (Positive, Neutral and Negative). Means and standard error of means of incorrect answers in the task appear in Table 1. Differences were not significant [$F(2,58) = 0.38$, $P > 0.5$].

3.2. Preliminary operations on ERP data

Before any statistical analysis of the ERP recordings was performed, two preliminary operations were carried out in them. Firstly, the average value of the respective baselines was subtracted from recordings, a necessary task in ERP research. Secondly, responses to the neutral trials were subtracted from responses to the emotional trials (both positive and negative). This second operation is recommendable due to the fact that variability between groups in ERP research is often conspicuous and not exclusively linked to the dependent variable under study (Picton et al., 2000; for example, low- or high-frequency interferences often affect dissimilarly to each group of subjects). In our particular case, and as can be observed in Fig. 3, even recordings obtained in neutral (or control) trials were clearly more negative in the high-trait-anxiety group than in the low-trait-anxiety group. Since neutral stimulation has not been reported to be associated with any attentional bias, it could be concluded that this negativity reflects the influence of interfering vari-

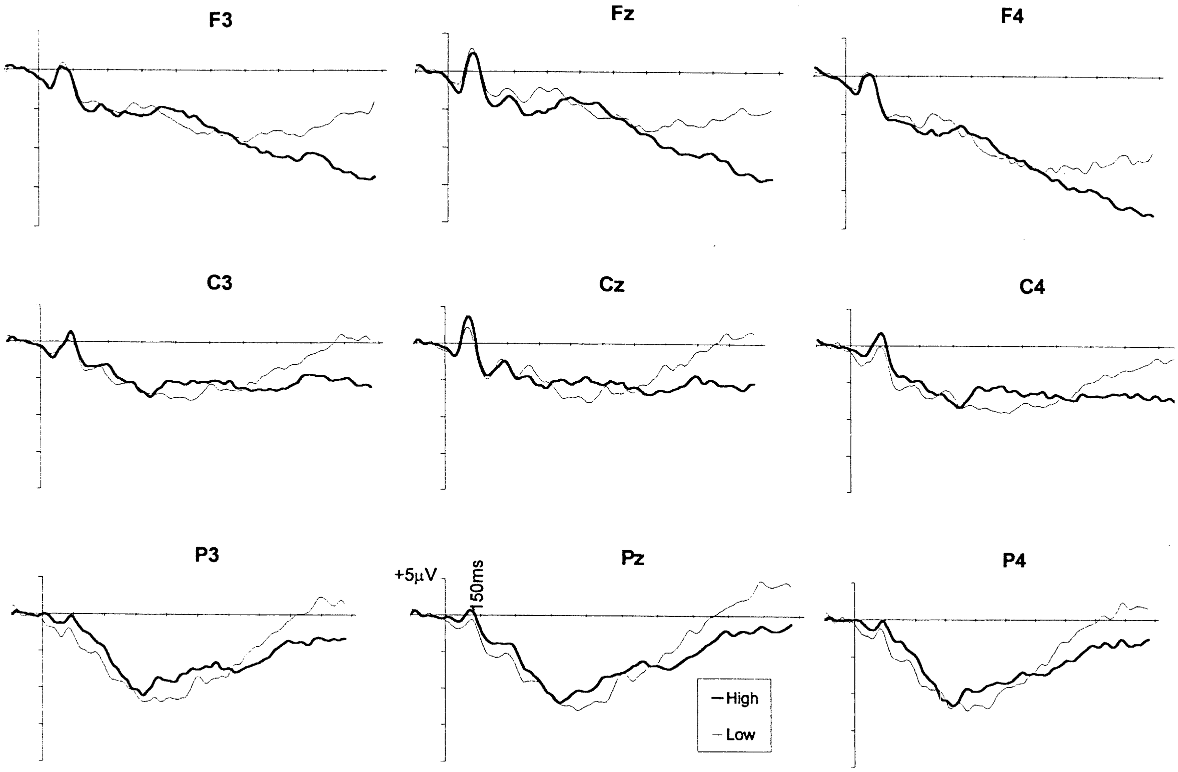

Fig. 3. Grand averages obtained in the neutral trials (i.e., trials in which the cue asked the detection of the neutral image in the target slide) at the nine scalp locations employed ($n = 30$). Recordings distinguish between high and low combination of trait and state anxiety. Scales and polarity are shown in Pz.

ables (i.e., variables unrelated to these biases nor to their interaction with the affective content of the stimulation). Subtracting the neutral-trial recordings (elicited by non-arousing, non-valenced stimuli), 'eliminates' or 'discounts' from responses all their non-affective aspects common to neutral and emotional trials. Thus, recordings submitted to the analyses described below were those obtained in negative and positive trials once recordings obtained in neutral trials had been subtracted. Fig. 4 shows grand averages of these 'after-neutral-subtraction' recordings.

3.3. Detection and quantification of ERP components: principal component analysis

As in the present experiment, early and late CNVs are not easily distinguishable in grand averages (except when S1–S2 is long), and a principal component analysis (PCA) should be employed to detect them. In fact, this technique has been repeatedly recommended for the detection and quantification of components when grand averages do not clearly show the ERP structure (e.g., Donchin and Heffley, 1978; Coles et al., 1986; McGillem and Aunon, 1987). This is the case of the present experiment, so components explaining most post-cue, pre-target (S1 to S2) ERP variance were extracted through PCA.

The decision on the number of components to select was based on the scree test (see, e.g., Cliff, 1987, for a description). Extracted components were then submitted to Varimax rotation. Following this selection criterion, and as it could be expected, two components or factors were extracted. Factor 1 explained 84.49% of total variance and Factor 2 explained 6.69% (59.67 and 31.51%, respectively, after rotation). Fig. 5 shows the rotated loadings plotted over time for these two components. Analysis

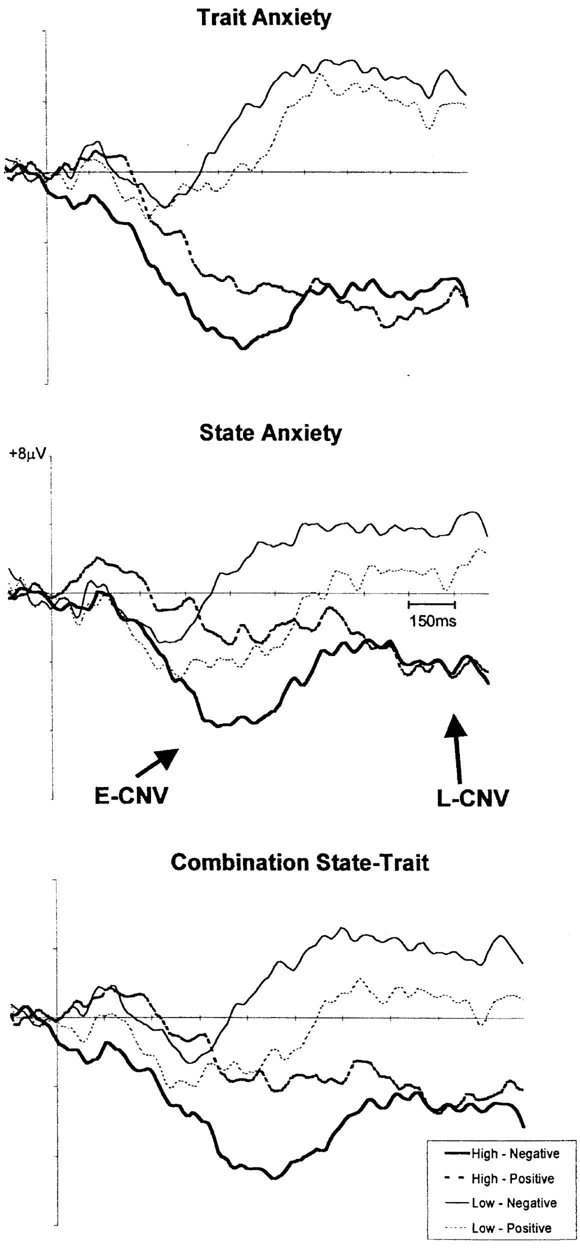

Fig. 4. Grand averages separating high and low groups of subjects ($n = 30$) according to their trait anxiety (top), state anxiety (middle) and the combination of both (bottom). In the three cases, an average of the nine recording channels is represented. Scales and polarity are shown in middle grand averages.

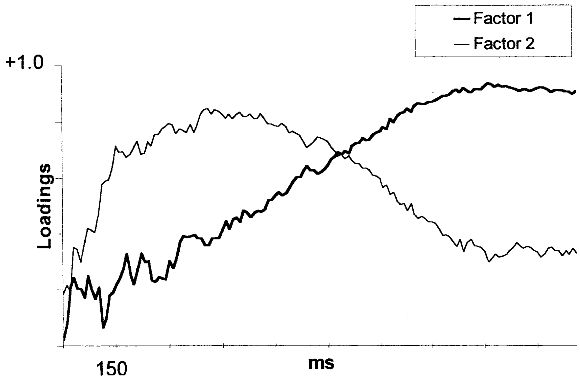

Fig. 5. Principal component analysis: factor loadings after Varimax rotation.

of peak-latencies observed in this figure associate Factor 1 with the long-latency variation marked as 'L-CNV' (late CNV) in grand averages (Fig. 4, middle), and Factor 2 with a relatively early negativity (peaking at 280 ms) signaled as 'E-CNV' (early CNV) in grand averages. These labels will be employed hereafter for these two PCA factors (instead of 'Factor 1' and 'Factor 2'), in order to make results more understandable.

3.4. ANOVAs on main effects

Possible interactions between the level of anxiety and the level of vigilance towards positive and negative stimulation were analyzed via three-way ANOVAs on both E-CNV and L-CNV factor scores. Basically, factor scores, which are calculated for each individual ERP, reflect the product of point loading by point amplitude. Therefore, amplitude and factor score are directly-related parameters. Within-subject factors were Trial type (2 levels: Positive and Negative, after subtraction of Neutral in both cases) and Laterality (3 levels: recordings at Left, Middle and Right electrodes). Between-subjects factor was Anxiety: Trait anxiety for one group of ANOVAs, State for the second group, and the Combination of the two (average of state and trait centiles) for the third group (two levels in each case: low—under centile 50—and high—equal to or over centile 50). In these cases too, the GG epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios, and post-hoc comparisons were made to determine the significance of pairwise contrasts, using the Bonferroni procedure (alpha = 0.05). The results on which we focused

Table 2
Results of ANOVAs regarding the interaction Trial Type (Positive, Neutral and Negative) by Anxiety (State, Trait, and their Combination, high and low in the three cases)

	Factor 1 (L-CNV)	Factor 2 (E-CNV)
Trait Anxiety	$F=1.771$, $P=0.261$	$F=1.862$, $P=0.183$
State Anxiety	$F=1.422$, $P=0.243$	$F=4.849$, $P<0.05$ ($P=0.036$)
Combination	$F=1.246$, $P=0.274$	$F=5.346$, $P<0.05$ ($P=0.028$)

$n=30$. Greenhouse–Geisser epsilon = 1 in all cases. Degrees of freedom = 1, 28.

Table 3
Results of ANOVAs regarding the interaction Trial Type (Positive, Neutral and Negative) by Anxiety (State, Trait, and their Combination, high and low in the three cases) by Laterality (Left, Middle, Right)

	Factor 1	Factor 2
Trait Anxiety	$F=0.453$, $P=0.638$	$F=2.256$, $P=0.116$
	G–G $\epsilon=0.939$	G–G $\epsilon=0.969$
State Anxiety	$F=3.065$, $P=0.570$	$F=1.641$, $P=0.205$
	G–G $\epsilon=0.966$	G–G $\epsilon=0.948$
Combination	$F=1.976$, $P=0.151$	$F=2.306$, $P=0.112$
	G–G $\epsilon=0.951$	G–G $\epsilon=0.958$

$n=30$. Degrees of freedom = 8, 224. G–G = Greenhouse–Geisser.

were those regarding the Trial type by Anxiety interaction (see Table 2) and the Trial type by Laterality by Anxiety interaction (Table 3).

Firstly, with respect to the Trial type by Anxiety interaction, analyses on L-CNV did not yield significant differences and, as can be appreciated in Table 2, differences were significant in E-CNV in contrasts referring to State and the Combination state–trait. Post-hoc comparisons indicated that in both the State contrast (Fig. 6, top) and the Combination state–trait contrast (Fig. 6, bottom), E-CNV amplitude significantly differed between the negative and the positive trials (being higher in the former case) only in the high anxiety group. Secondly, analyses regarding the interaction Trial type by Laterality by Anxiety (Table 3) did not yield significant effects.

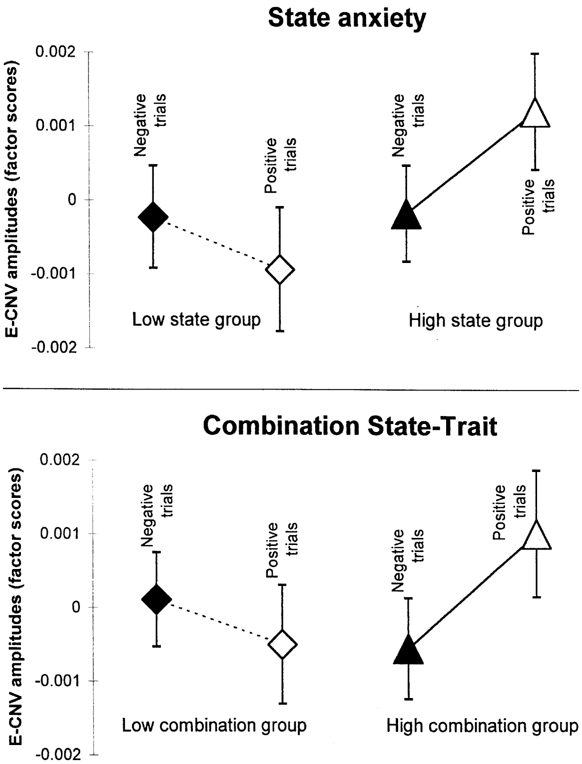

Fig. 6. Mean values of factor scores (directly related to amplitudes: the more negative, the higher the CNV amplitude) corresponding to E-CNV amplitudes as a function of Trial type and Anxiety (only the types of anxiety that yielded significant results are represented: State at the top, Combination state/trait at the bottom). Error bars represent the standard error of means. Solid lines between means mark significant differences, and, dotted lines marks, non-significant.

4. Discussion

Analysis of brain electrical activity elicited by emotional stimulation supports the existence of vigilance biases in anxious subjects. Specifically, the amplitude of the early CNV is greater when anxious subjects are vigilant towards negative affective stimulation than when they must be vigilant towards positive stimuli, a bias not observed in non-anxious subjects. As explained in the Introduction, early CNV amplitude is directly related to vigilance-related attention. The emotional stimuli used in the present study are characterized by having a balanced arousal content, so that the effects detected here may only be attributed to the stimular valence. Thus, the present results support the idea that vigilance bias in anxiety is more characterized by a 'cognitive-affective coherence' or 'mood congruency' (MacLeod and Mathews, 1988) that involves a greater mobilization of attentional resources towards threatening information than by a general 'emotionality' that directs these resources to every emotional event, positive or negative.

As found in many behavioral studies, the greatest effect of vigilance bias has been observed in subjects scoring high both in trait and in state anxiety. It is likely that the combined trait–state measure is the most appropriate index of subjects' general level of anxiety. According to the interaction theory (Eysenck, 1992), subjects presenting high trait anxiety also need to be in a situation of high state anxiety (or under stress) to present attentional biases. In fact, the present data indicate that subjects scoring high in trait anxiety alone did not present any cerebral index of vigilance bias. However, our results suggest that subjects scoring high in state anxiety alone present a bias (significant for ANOVAs but not for Bonferroni post-hoc comparisons) similar to the bias present in subjects scoring high in the state–trait combination. The fact that high state anxiety is associated with attentional biases has been reported previously in research using pictorial stimulation (facial expressions: Bradley et al., 1998), but not when threatening words are presented. This confirms the fact, mentioned in the Introduction, that pictorial stimulation is more capable of eliciting attentional biases than words. Moreover, it confirms that the threat value of the stimulation interacts with the level of both state and trait anxiety to determine the extent of the vigilance bias. In other words, attention is more engaged as the threat value of the stimulus increases, even in individuals with low trait and state anxiety.

Present (and previous) data indicating that the bias is absent in non-anxious subjects need to be reconciled with those suggesting that negative events elicit more rapid and/or more prominent emotional responses (involving cognitive and physiological changes) than non-negative events, regardless of the presence or absence of anxiety (see review by Cacioppo and Gardner, 1999). The adaptive and evolutionary advantages of this general 'negativity bias' are obvious: the consequences of a dangerous or harmful event are often much more dramatic than the consequences of ignoring or reacting slowly to neutral or even appetitive stimuli (e.g., Ekman, 1992; LeDoux, 1990; Öhman, 1992). The involvement of attention in this bias has scarcely been studied, though the privileged access of negative stimulation to attentional resources has been indirectly suggested by studies on autonomic physiological responses (Öhman et al., 1993) and behavioral studies using reaction time (Pratto and John, 1991) or visual fixation (Fiske, 1980) as dependent variables. Thus, it could be expected that, to a certain extent, vigilance-related brain activity would also show a bias in non-anxious subjects.

The presence of the bias only in anxious subjects may admit two explanations. Firstly, differences between anxious and non-anxious subjects in this regard could depend on respective thresholds (McNally, 1998; Mogg and Bradley, 1998): non-anxious subjects might need 'more threat' in the stimulation in order to preferentially mobilize their attentional resources to negative stimulation. Secondly, the general 'negativity bias' might appear only when the individual has to process already-perceived threatening information (an urgent response is needed only once the stimulus appears), but not when the subject is 'exploring' his/her environment (e.g., searching for a target). In this latter case, vigilance biases towards negative information could appear in anxious but not in non-anxious subjects. It should be pointed out that previous ERP data are more in keeping with the second explanation. In this sense, post-target components (reflecting input-processing-related attention to already-perceived emotional stimulation: see the Introduction) show indicators of negativity bias in normal samples[1] (Carretié et al., 2001; Ito et al., 1998). Meanwhile, and in concordance with the present results, vigilance-related (post-cue/pre-target) activity such as that analyzed here has not shown

[1] The term 'normal samples' refers to experimental samples not selected, as in the present experiment, on the basis of the level of anxiety of each subject. These samples, selected independently from trait or state anxiety levels, are assumed to be, as the general population, normally distributed with respect to this affective disorder.

signs of negativity bias in normal samples in studies on CNV and emotional stimulation (Carretié et al., 2001; Klorman and Ryan, 1980; Yee and Miller, 1987). However, the possibility that the two explanations (threshold and type of attention) may coexist cannot be discarded on the basis of available data. The fact that behavioral studies encounter important difficulties in discriminating vigilance-related from input-processing-related attention through the type of responses they measure makes ERPs into an essential tool for future research on this subject.

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