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The influence of emotional context on attention in anxious subjects: neurophysiological correlates

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Abstract

Several studies have shown the influence of threatening context on level of attention to target environmental stimuli. The present experiment explored the possibility that this influence of aversive context is particularly strong in anxious subjects, due to their known attentional bias towards negative information. Event-related potentials, that provide a direct index of attention-related cerebral processing, were recorded in 27 participants selected from a larger sample of 250, as a function of their trait anxiety scores (14 high, 13 low). State anxiety was also measured in selected subjects. Several contexts were presented: positive, negative, relaxing and neutral, and participants were instructed to attend, within these contexts, to a series of auditory stimuli. Threatening context triggered an increase in attention to these auditory stimuli only in conditions of high state anxiety, this increase being reflected in the greater amplitude of the P2 component, which is related to attentional processes. There were no significant differences in relation to trait anxiety. Data show that threatening context and high level of state anxiety in combination increase the quantity of attentional resources directed to the environment.

Keywords: State anxiety; ERPs; Attentional biases; Emotional context

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1. Introduction

Several cognitive theories (Beck, 1976; Bower, 1981; Williams, Watts, MacLeod, & Mathews, 1988, 1997) postulate that attentional biases towards negative information can be characterized as being a cognitive marker of anxiety, and, moreover, as provoking and maintaining this affective condition (Mathews & Macheod, 2002; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). These theories have considerable experimental support, according to several behavioral studies (Bradley, Mogg, Falla, & Hamilton, 1998; MacLeod & Mathews, 1988; Mathews & Mackintosh, 2000; Mogg, Mathews, & Eysenck, 1992; Taghavi, Moradi, Neshat-Doost, Yule, & Dalgleish, 2000) and also to brain activity studies (Carretié, Mercado, Hinojosa, Martin-Loeches, & Sotillo, 2004; Weinstein, 1995). Some researchers from behavioral approaches consider the affective context (e.g., a stressful situation) as a factor capable of triggering the appearance of the attentional bias in anxiety-prone subjects (Mogg, Bradley, & Hallowel, 1994).

Furthermore, studies of brain electrical activity (event-related potentials or ERPs) show the capacity of affective context to produce the mobilization of attentional resources towards target negative (Böcker, Baas, Kenemans, & Verbaten, 2001; Cuthbert, Schupp, Bradley, McManis, & Lang 1998) and even innocuous stimulation (Surakka, Tenhunen-Eskelinen, Hietanen, & Sams, 1998). Thus, according to ERP data, a negative visual context increases the level of attention.

Taking into account both research lines, it is suggested that the increase in attentional processing produced by a negative context towards target environmental stimuli will be greater in anxious individuals than in non-anxious individuals. Despite the extensive research to date, a question that remains open concerns the type of anxiety that is most sensitive to the influence of emotional context, that is, whether context-associated attentional bias is better explained by a personal characteristic (trait anxiety) or by a temporary condition of anxiety or stress (state anxiety). According to the interaction hypothesis (Eysenck, 1992), attentional biases become more evident in high trait-anxious individuals in stressful conditions (Broadbent & Broadbent, 1988; Egloff & Hock, 2001). However, other authors argue that high state-anxious individuals allocate more attentional resources towards threatening stimulation irrespective of their level of trait anxiety (Mogg, Mathews, Bird, & McGregor-Morris, 1990), and also that they present greater difficulties for disengaging attention from this type of stimulus (Fox, Russo, Bowles, & Dutton, 2001).

At present, there are still no brain activity data on the role of anxiety in the influence of affective context on attention to target environment stimulation. Studies on brain electrical activity provide a useful complement to the information obtained from behavioral research, since they provide more direct data on attention-related cerebral processing (Mangun & Hillyard, 1995). The attentional processing related to auditory stimuli is reflected, among others, by the P2 component (Hugdahl, 1995). This component is enhanced in the presence of unexpected auditory stimuli, which are capable of attracting more attention (Holcomb, Ackerman, & Dykman, 1986). Moreover, the component is modulated by the attentional demands of the task (Johnson, 1989), and has been successfully employed as an index of auditory attention (Bernal et al., 2000).

Thus, the present research attempts to study the influence of emotional context on the attention level of anxious individuals to target environmental stimuli through ERPs, and specifically through the analysis of the P2 component. A secondary scope is to determine which type of anxiety (state or trait) is more susceptible to influence from the affective context. One of the procedures most commonly used for generating an affective context in psychophysiological studies consists in the visual presentation, over a long period of time (normally several minutes), of emotionally positive, negative and neutral images (Cuthbert et al., 1998; Lang, Greenwald, Bradley, & Hamm, 1993; Müller, Keil, Gruber, & Elbert, 1999). It is this procedure that will be used in the present research. At the same time as presenting the affective context, we shall present neutral auditory stimuli in an *oddball paradigm*, assessing attention level to them through the P2 amplitude, usually explored through this experimental paradigm (Amenedo & Díaz, 1998). A description of the characteristics and rationale of this experimental paradigm will be explained in Section 2.2.

2. Methods and materials

2.1. Participants and selection criteria

Thirty-two right-handed students with normal hearing and normal or corrected-to-normal visual acuity from the Universidad Autónoma de Madrid (Spain) participated voluntarily in this experiment. They were selected from an initial pool of 250 participants according to their scores on the trait scale of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1988). The ERP data of five participants were discarded, as explained below. The remaining 27 (21 women and 6 men) were aged between 20 and 33 years (mean = 22.07, S.D. = 2.97). Fourteen of them showed high trait-anxiety (over centile 65; 11 women and 3 men) and 13 showed low trait-anxiety (under centile 35; 10 women and 3 men). Four to twelve weeks after the date on which the trait scale of the STAI test was applied, participants were recalled for the recording phase. Once in the laboratory, and just before this recording phase began, participants filled out the state scale of the STAI test (10 subjects scored over centile 50 in state anxiety—7 women and 3 men—and 17 under centile 50—14 women and 3 men).

2.2. Stimuli and procedure

The experimental design required presentation of visual and auditory stimuli. The former generated the emotional context, while the latter were the neutral target stimuli (which were presented simultaneously with the visual stimuli) to which participants were required to attend as part of the task. Participants sat in an electrically and acoustically isolated room in a comfortable chair, 1 m from the screen. They were told initially to look continuously at a point located in the center of the screen on which the pictures would appear. This fixation point was at participants' eye level. The visual stimuli consisted of color slides. The resulting angle of vision was 10° with respect to the long, vertical side of the slide, and 6.7° with respect to the horizontal side. Each one was shown for 3 min, and order of presentation was counterbalanced. These visual stimuli generating the emotional context were of four types. Thus, one of the pictures showed an opposite sex nude (arousing positive image, A+), another showed a wolf jaw (arousing negative image, A−), the neutral image (N) showed railway tracks, and the final one, corresponding to the relaxing image (R), showed a landscape. Size and luminosity were similar across all the pictures.

Auditory stimulation began 10 s after visual stimuli onset. A total of 150 auditory stimuli were presented, following the oddball paradigm: they consisted in two different tones (1000 Hz, 80% of trials, and 1500 Hz, 20% of trials, usually called 'standard' and 'deviant' or 'odd', respectively). These 150 auditory stimuli were divided into three series of 50 stimuli. Duration of each auditory stimulus was 400 ms, with an intertrial interval of 700 ms. Participants were asked to make a 'mental count' of the deviant auditory stimuli (indicating, at the end of each of the three series, the total number). Before the start of the recording phase, participants were familiarized with the task by means of two training series lasting 10 s each. Data from five of the 32 participants were removed because they deviated by more than 20% from the correct responses (counting deviant stimuli). This paradigm, customarily employed in research on ERPs, is useful because it permits the experimenter to distinguish the effect of the experimental treatment on the purely perceptual processes, occurring with all the stimuli, standard (or non-attended) and deviant (or attended), from the effect on active attention processes, which occur only with the stimuli that participants must attend (deviants), and which are relevant to the task (Picton & Hillyard, 1988).

The 27 participants 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 content (from −2, relaxing, to 2, arousing) of the pictures, the two most important dimensions for explaining the principal variance of the emotional meaning. The results of this test are described as follows.

2.3. ERP recording

Electroencephalographic data were recorded at F3, Fz, F4, C3, Cz, C4, P3, Pz and P4, using Ag/ClAg electrodes, the nosetip being the reference. Electrode impedances were always kept below 7 kΩ. A bandpass filter of 0.06–35 Hz was used for the recordings amplifiers. The EEG was sampled at 105 Hz for 700 ms

(100 ms being prior to auditory stimuli onset). An EOG was recorded infra- and supra-orbitally at the left eye. Trials where the EOG activity was greater than 40 μV were automatically rejected and repeated. None of the 27 participants were eliminated because of ocular artifact rate, since the figure for this was less than 15% of trials.

3. Results

3.1. Control analyses

As explained in the Section 2, each participant filled out a bidimensional scaling test for each picture after the recording sessions. This test assessed the valence and the arousal content of the visual stimuli used to generate the affective context. Analyses on these assessments given by participants were carried out in order to confirm, first, that their affective valence was that which was assumed a priori, and second, 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 arousal dimensions, using Stimuli (four levels: A+, A−, N, R) as factor. The Huynh–Feldt (HF) 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 Tukey procedure (alpha = .05). ANOVAs yielded significant differences in both valence [$F(2, 48) = 88.125$, HF epsilon = 0.638, $P < .001$] and arousal [$F(2, 57) = 66.866$, HF epsilon = 0.770, $P < .001$]. Post hoc contrasts indicated that A+ and A− showed different valence but not different arousal. A+ and A− differed from N in both arousal and valence. A+ and R differed in arousal. Finally, A− and R presented different assessments in both arousal and valence.

3.2. Previous operations on ERP data

Before any statistical analysis of the ERP recordings was performed, two preliminary operations were carried out on them. First, the average value of the respective baselines was subtracted from recordings, a necessary task in ERP research. Second, the ERPs evoked by tones in the neutral (N) context were

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 27 participants to the four types of pictures (neutral, positive, relaxing and negative)

	N	A+	R	A−
Arousal	−0.074 (0.178)	1.185 (0.146)	−1.481 (0.188)	1.296 (0.113)
Valence	0.148 (0.099)	1.630 (0.105)	1.852 (0.067)	−0.704 (0.198)

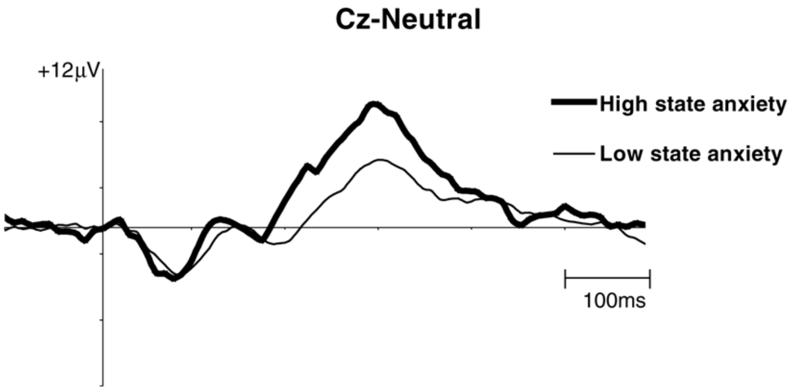

Fig. 1. Grand averages obtained in response to auditory stimuli under the neutral context at Cz. Recordings distinguish between high and low state-anxiety participants ($n = 27$).

subtracted from the ERPs evoked by tones in the emotional contexts (A+, A− and R). This operation is recommended, due to the fact that variability between groups in ERP research is often high, and not linked exclusively to the dependent variable under study (Picton et al., 2000). In our particular case, and as can be observed in Fig. 1, even recordings obtained in neutral (or control) contexts were clearly more positive in the high-state-anxiety group than in the low-state-anxiety group. Since neutral contexts have not been reported as being associated with any attentional bias, it could be concluded that this positivity reflects the influence of interfering variables (i.e., variables unrelated to attention biases or to their interaction with the affective content of the stimulation). Subtracting the neutral-context recordings (elicited during non-arousing, non-valenced situations) ‘eliminates’ from responses all their non-affective aspects common to neutral and emotional contexts. Thus, recordings submitted to the analyses described below were those obtained in negative, positive and relaxing contexts once the recordings obtained in neutral contexts had been subtracted. These new ‘subtracted’ categories will be labeled A+s, A−s and Rs.

3.3. Analyses on electrophysiological effects of context-induced bias

Fig. 2 shows the grand averages for A+s, A−s and Rs. As it can be seen, a positive wave occurs at approximately 180 ms from stimulus onset. This is related to attentional aspects (Mangun & Hillyard, 1995), and will be labeled P2. In order to quantify this component, the amplitude of the most prominent peak occurring within the 150–210 ms window was computed in each individual ERP. P2 amplitude is highest at Cz (see also Iragui, Kutas, Mitchiner, & Hillyard, 1993).

With the aim of studying associations between anxiety level and participants’ attention to the tones in each emotional context, we carried out two analyses: one

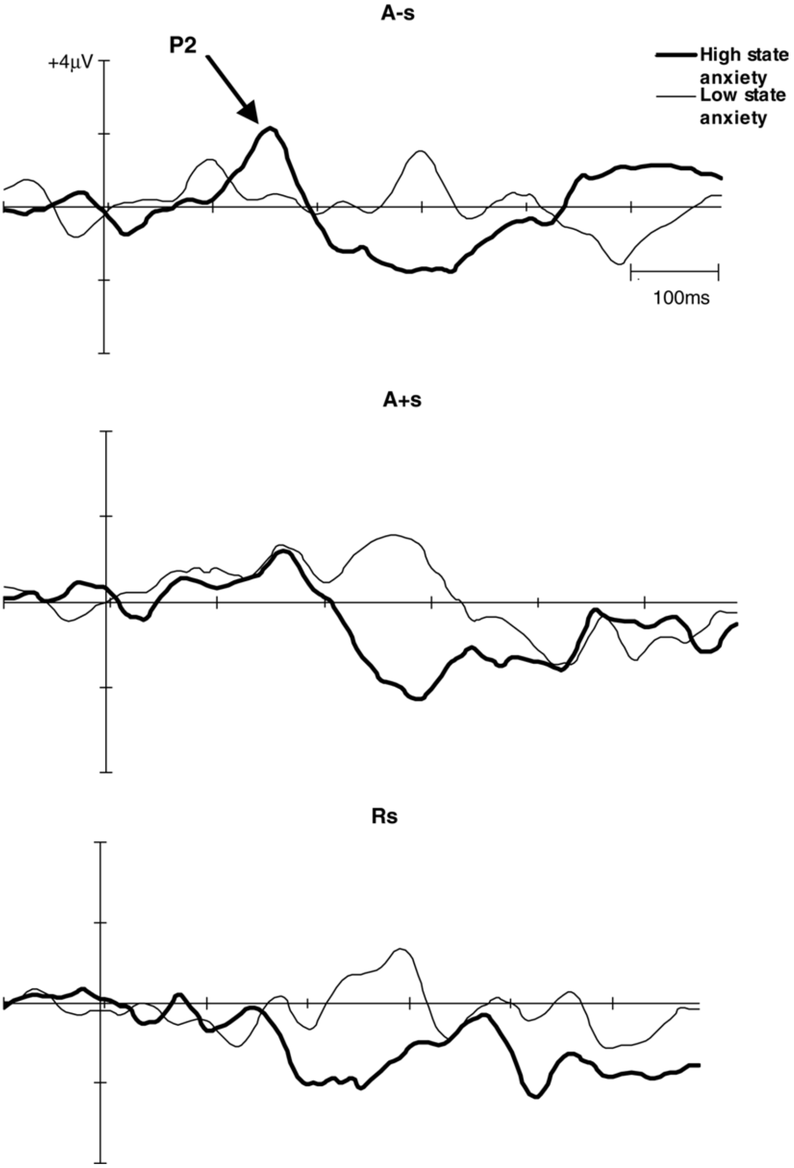

Fig. 2. Grand averages at Cz, separating high and low state anxiety participants ($n = 27$) in the three types of emotional minus neutral contexts (A−s, A+s and Rs). Scales and polarity are shown in top grand averages.

for the standard and one for the deviant auditory stimuli. The Huynh–Feldt (HF) epsilon correction was applied to adjust the degrees of freedom of the *F*-ratios.

3.3.1. Analyses on standard stimuli

First, we performed a repeated-measures ANOVA on amplitude of the P2 component to standard (non-target, non-attended) stimuli, including three factors: Context Stimuli (three levels: A+s, A−s and Rs), Channels (nine levels: F3, Fz, F4, C3, Cz, C4, P3, Pz and P4) and Anxiety (two levels: high and low state anxiety, in one analysis, and high and low trait anxiety, in another). As expected, there were no significant effects of the interaction between experimental treatment (affective context) and participants' trait anxiety level and state anxiety level on P2 amplitude. This finding indicates that there is no influence of emotional context on purely perceptual processes, which are those elicited by standard or non-attended auditory stimulation.

3.3.2. Analyses on deviant stimuli

Secondly, we computed a repeated-measures ANOVA on the amplitude of the P2 component associated with the deviant auditory stimuli (which were to be actively attended). The factors included in this case were once again Context Stimuli (three levels: A+s, A−s and Rs), Channels (nine levels: F3, Fz, F4, C3, Cz, C4, P3, Pz and P4) and Anxiety (two levels: high and low state anxiety, in one analysis, and high and low trait anxiety, in another). Interaction between Stimuli and State anxiety produced significant effects [$F(2, 50) = 0.227$, HF epsilon = 1.000, $P < .05$]. Since the Context Stimuli by Channels by Anxiety interaction may also be considered as significant [$F(16, 400) = 1.953$, HF = 1.000, $P = .058$], post hoc analyses were carried out in order to detect those scalp locations showing significant effects. Post hoc (Tukey; alpha = .05) comparisons revealed that, in high state-anxiety subjects (and not in low-anxiety subjects), P2 amplitude to A−s was greater than that to A+s and Rs at frontal and central sites (Fz, F4 and Cz). On the other hand, low state-anxiety subjects (but not high-anxiety subjects) presented higher P2 amplitudes in response to A+s than in response to A−s and Rs, though this pattern was only observed at Cz. Interaction between Stimuli and Trait anxiety or between Stimuli, Trait anxiety and Channels did not show significant differences [$F(2, 50) = 0.039$, HF epsilon = 1.000, $P > .05$]. Fig. 2 shows the grand averages of this component, corresponding to each type of visual stimulus, separating data as function of state anxiety. Fig. 3 illustrates the mean P2 amplitudes in response to deviants with respect to State anxiety and emotional context.

4. Discussion

Data for brain electrical activity (specifically, amplitude of the P2 component) show that threatening affective context produces an increase in attention to target stimuli from the environment in people with high levels of state anxiety. This increase in the assignment of attentional resources does not occur in contexts of a positive nature, thus suggesting that valence is the affective dimension that mainly explains the attentional differences reflected in the P2 component. P2 amplitude is, as mentioned in the Section 1, an index of neural activity associated with

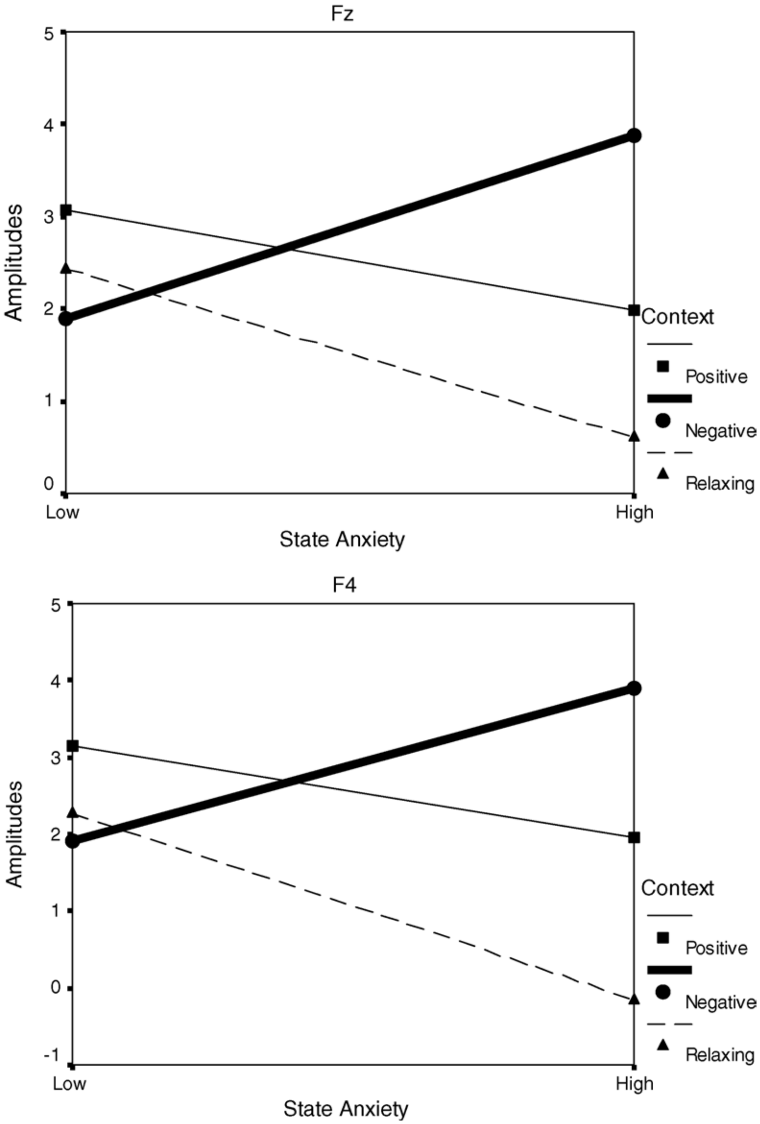

Fig. 3. Mean P2 amplitudes in response to auditory deviant stimuli under the three types of emotional contexts (positive, negative, relaxing) at Fz, F4 and Cz, where results were significant.

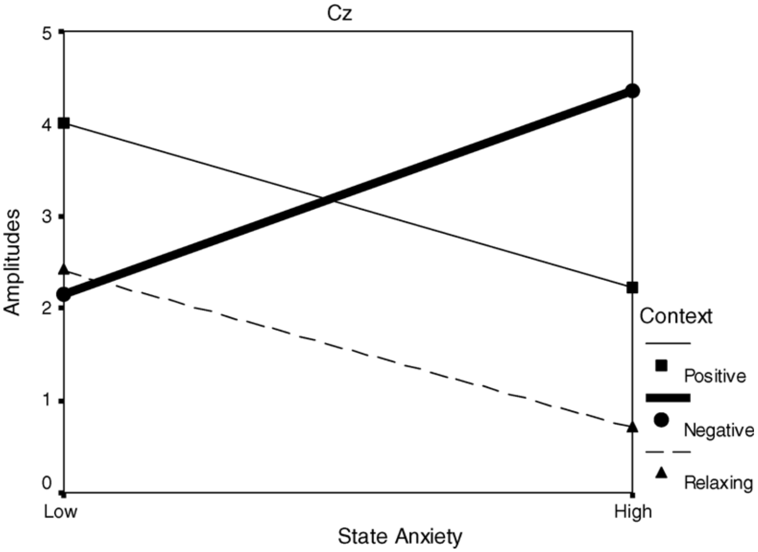

Fig. 3. (*Continued*).

attention to auditory stimuli (e.g., Bernal et al., 2000; Holcomb et al., 1986; Hugdahl, 1995; Johnson, 1989; Mangun & Hillyard, 1995). On the other hand, trait anxiety is not influenced by the affective charge of the emotional context.

Some authors suggest that the increase in attentional processing may derive from the fact that people with high state anxiety, present general hypervigilance towards stimulation from the environment (Eysenck, 1992). In the light of our data, we suggest that high state-anxious individuals deploy specific hypervigilance (i.e., only—or, at least, mainly—under negative situations or threatening contexts). In other words, increase in attention towards stimulation from the environment would appear to be influenced by the combination of the threatening value of the context and the level of individual state anxiety (Bradley, Mogg, & Millar, 2000). Results obtained are consistent with other findings from behavioral studies, in which state anxiety, more than trait anxiety, is considered as chiefly responsible for the appearance and mediation of attentional biases towards emotionally negative information (Bradley et al., 2000; Mathews, Mogg, Kentish, & Eysenck, 1995).

In principle, these attentional biases are of considerable value for survival and are adaptively advantageous, since they permit the organism to detect danger from the environment and react to it rapidly (Öhman, 2000). In fact, the existence of a system for the urgent processing of fear (see Armony & Ledoux, 2000, for review), in which the amygdala plays a central role, supports the adaptive importance of preferential processing of stimuli that represent potential danger. Indeed, the induction of negative emotional states increases the activation of the amygdala (Reiman, Lane, Ahern, & Schwartz, 1997a). Present data suggest that both state anxiety and negative or stressing contexts may increase the activation of this threat-detection system. As mentioned above, we have found that frontal and central sites are particularly sensitive to the observed effects. This insight is consistent with previous brain activity studies which showed an increased activity at prefrontal areas during anxiety contexts (Davidson et al., 2000; Reiman, 1997b). Furthermore, other studies describe that prefrontal cortex, which receives inputs from the amygdala (Vuilleumier, 2002), is responsible for the affective evaluation of the incoming information (Rolls, 1999).

Finally, it is shown that ERPs, and, in particular, the P2 component, constitute a useful tool for studying these attentional biases, and could be used in conjunction with behavioral data for assessing anxiety disorders. In future research, it would seem interesting to study these attentional biases in clinical samples, making use of electroencephalographic techniques, in order to build on the findings obtained with a non-clinical sample.

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