

The perception of fearful and happy facial expression is modulated by anxiety: an event-related potential study

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Abstract

Anxiety is supposed to interfere with cognitive and emotional processing and high level of trait-anxiety has been associated with an attentional bias for fearful faces, even in sub-clinical anxiety. On the basis of the Spielberger State and Trait Anxiety Inventory (STAI), twenty students were grouped as low vs. high anxious. Pictures from the Ekman and Friesen series were used in an event-related potentials study to investigate the neurophysiological correlates of the emotional processing of fear and happiness in sub-clinical anxiety. Subjects were confronted with a visual oddball design, in which they had to detect, as quickly as possible, deviant happy or fearful faces amongst a train of standard stimuli (neutral faces). Anxiety does not modify early perceptual (N100, P100, N170, VPP) or attentional (N2b) component, but later components are affected. Indeed, high anxious subjects are faster to detect deviant faces as suggested by earlier reaction times and P3b component. However, they show a reduced ability to process the emotional content of faces, this deficit being indexed by a decreased N300 component. Indeed, N300 is supposed to be particularly sensitive to affective features of stimuli rather than to physical characteristics. We propose that the earlier P3b observed in high anxious subjects could be interpreted as a way to overcome the deficient emotional appraisal by a more salient conscious processing.

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Different lines of evidence suggest that anxiety interferes with emotion processing in such a way that anxious subjects are particularly sensitive to threatening information [10,14,20], and show, for instance, a *processing bias* towards threat-related facial expressions [10,20]. It has been shown that different forms of anxiety exist, and that they all affect emotion perception. Indeed, biases in vigilance appear when emotional stimuli match the domain of current concern for the subjects [13]: For instance, vigilance is biased towards physical threat in *panic disorders*, towards socially threatening situations in *socially anxious* [14], and towards their idiosyncratic worries in *generalized anxious people* [13]. In the present study, we will focus on normal subjects showing anx-

ious tendencies, because some studies have already suggested the presence of a bias towards threatening information in sub-clinically anxious people [8,15,20] with verbal material. To our knowledge, only one study has addressed [10] whether sub-clinical anxiety elicits, as in clinical conditions, a bias towards threatening visual material, and more specifically, towards visual emotional facial expressions (EFE). However, the neurophysiological origin of this bias has not yet been investigated.

Fear expression is a socially threatening stimulus, and a particularly important signal to process as it often warns off the potential presence of a danger in the environment, and prepares the individual to confront it or to escape from it [10,17]. Many studies have shown that fear is processed in an automatic and unconscious way, and that this processing is mainly sustained by the activation of the amygdala [16,17].

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Consequently, the perception of fear has been shown to be modified by anxiety, in such a way that increased attentional resources seem to be devoted to fearful faces in sub-clinical anxious subjects [10]. Therefore, studying the role of such a bias in the aetiology and persistence of anxiety has revealed to be of the greatest relevance [14]. The bias for threatening information has been mainly showed in behavioural studies, using for instance designs such as the dot probe detection task or the modified Stroop Colour naming task [12,13]. Surprisingly, Bradley et al. [3] also showed an increased processing as well for threat as for *happy* faces. This was interpreted as an amplified vigilance for emotional stimuli in general. The question whether this bias is, in generalized anxiety disorder and in non-clinical anxiety, only linked with negative EFE, or could also be found with positive ones, is still matter of debate.

Our aim is to investigate how non-clinical anxiety affects emotional processing, more particularly with regard to emotional facial expression (EFE) of fear and joy. Event-related potentials (ERPs) can help answer this question, due to their excellent temporal resolution. Therefore, comparing normal subjects with high and low scores on an anxiety scale with ERPs allows to follow the temporal course of the information-processing stream and locate the level at which the above-mentioned bias occur.

For this purpose, we used an emotional oddball paradigm, in which participants have to detect an infrequent deviant stimulus among a series of frequent standard stimuli [4]. The oddball components, resulting from the subtraction of waveforms evoked by standards and deviant stimuli, distinguish attentional and decisional (or response-related) steps and offer the advantage of being able to characterize the level of processing which would be modulated by anxiety level. Three specific ERP components are indeed produced when the subject has to detect rare stimulations. First, the N2b component, maximally recorded at occipital sites around 250 ms, and its positive counterpart at frontal sites called the P3a. The N2/P3a complex is known as a bipolar “attentional orienting complex” [4]. The N2b component refers to the attention switch needed to take a new information into account, and the P3a component is sensitive to the degree of novelty of the deviant information [4]. Second, the P3b component, peaking at parietal sites around 450 ms. This positive wave arises when an attended stimulus is detected [11], and should reflect decision making and premotor response-related stages [4,5,11]. However, it could be difficult to justify a possible difference appearing on these components for an emotional purpose (and not for physical differences per se). A third ERP component named N300 makes it possible to answer this question. This monopolar component, a negative deflexion peaking around 300 ms at central sites, is supposed to be particularly sensitive to emotional stimulation [7]. N300 would reflect an affective processing and is few affected by cognition [7], in such a way that it reacts more to affective features of stimuli rather than to physical characteristics [7]. For instance, Schutter et al. [18] have related N300 to the

arousal of the stimuli [18], with an enhanced N300 for angry facial expression, attributed to a more elaborated evaluation of the relevant stimuli. Consequently, we can use this wave as a cue to investigate the depth of the emotional processing (for a commentary about N300, see Kayser and Tenke [12]).

Moreover, we still have access to the conventional ERP components associated with the basic processing of faces. Among them, the bipolar P100/N100 complex is typically described as reflecting primary visual analyses [4]. Then, two components are usually considered as face-specific: the bilateral N170 recorded at occipito-temporal sites (P7 and P8) and its positive counterpart at Cz called the Vertex Positive Potential (VPP, [5]). N170 has been described as unaffected by facial expressions [10], but some studies showed N170 modulations with valence of visually presented emotions [1,5].

Consequently, ERP components evoked in response to face stimuli will provide further information about the processing of emotional visual information and will allow to define more precisely the level of occurrence of the processing bias in anxiety.

We propose that emotional processing in anxious subjects will be prone to various modifications, visible with the ERP technique. As anxiety is known to affect the processing of emotional stimuli as compared to neutral ones, we postulate a modification of ERP components specifically related to this evaluation, namely the N2b, the N300 and the P3b. An alteration of N2b would reflect an attentional deficit, while a disturbed N300 could be interpreted as a deficit in the evaluation of emotional content of the stimulus, and an affected P3b could index disturbed conscious decisional processes.

On the other hand, insofar the classical ERP components, such as P100, N100 and N170, reflect the basic perceptive processing of stimuli, and that our aim is to work with subjects with anxious tendencies and not with in-patients, we do not postulate any effect on early ERP components.

Moreover, in non-clinical anxiety, we expect a more general enhanced vigilance rather than specific and powerful biases towards threatening stimuli.

Twenty participants (right-handed, with normal/corrected vision, and without neurological disease) were selected based on their score on the Spielberger Trait Anxiety Inventory (STAI, [19]) and 13-items Beck Inventory Scale [2] among 128 University of Louvain students. The distinction between high and low anxious was made by median splits on standardized measure of trait-anxiety (STAI-T: median = 50), and we chose students with similar scores on the Beck Inventory Scale to create two original groups. Ten students (mean age: 22.4; S.D.: 4.14) were grouped as low-anxious (LA: mean trait-anxiety: 38.9; S.D.: 7.14), and 10 (mean age: 22.3; S.D.: 2.58) as high-anxious (HA: mean trait-anxiety: 59.7; S.D.: 5.06).¹ Both groups comported eight female and two male participants. The 13-items Beck Inventory Scale [2] was also

¹ The scores on Spielberger scale group the subjects as follows: less than 36: very low; 36–45: low; 46–55: normal; 56–65: high; more than 65: very high [19].

completed by subjects, as depression covariates with anxiety and affects EFE perception [13] and we checked that groups were not depressed (general mean: 4.5; S.D.: 3.56), and not contrasted neither on Beck Score ($t(9) = -1.983$; NS) nor on age ($t(9) = 0.061$; NS), but differed on trait-anxiety level ($t(9) = -6.638$; $P > 0.001$).

The experimental design follows an oddball paradigm. Stimuli consisted in four faces (selected from highly standardized set of pictures of Ekman and Friesen series, [9]; actors PE, JJ, MO and PF) with NEUTRAL, HAPPY and FEARFUL expressions.

Sixteen blocks were displayed, each defined by 100 stimuli (84 frequent stimuli; for instance: face A neutral; 8 deviant face A happy and 8 deviant face A fear). The presentation order of the 16 blocks was counterbalanced across subjects. The participants had to point out as quickly as possible the occurrence of a deviant stimulus by pressing a mouse button with their right index finger.

During the ERPs recording, subjects sat on a chair in a dark room with their head placed 1 m from the screen and restrained in a chin rest. The screen background was black. Stimuli were 6 cm horizontal and 8 cm vertical, subtending a visual angle of $3 \times 4^\circ$ and faces were presented for 500 ms. A black screen was displayed as intertrial interval, lasting randomly between 1300 and 1600 ms, but subjects had 1500 ms to answer from stimulation onset.

The EEG recordings were performed with 32 electrodes mounted in an electrode Quick-Cap with the standard 10–20 International System and intermediate positions. Recordings were made with a linked mastoid physical reference. The EEG was amplified by battery-operated SYNAMPS amplifiers with a gain of 30,000 and a band-pass of 0.01–100 Hz. The impedance of all electrodes was kept below 20 k Ω . EEG was continuously recorded (sampling rate 500 Hz, NeuroScan software) and vertical electrooculogram (VEOG) was recorded bipolarly from electrodes placed on the supraorbital and infraorbital ridges of the left eye. Trials contaminated by EOG artefacts (mean of 15%) were eliminated off-line by computing an average artefact response based on a percentage (in this case, 20%) of the maximum eye movement potential. The EOG response is therefore subtracted from the EEG channels on a sweep-by-sweep, point-by-point basis in order to obtain ocular artefact-free data. Epochs beginning 150 ms prior to stimulus onset and continuing for 850 ms were created. Codes synchronized with stimulus delivery were used to average selectively the epochs associated with different stimulus types. Two parameters were coded for every stimulus: (1) the type of the stimulus (rare HAPPY; rare FEAR; and in order to have the same number of averaged frequent stimuli, only the frequent stimuli preceding the deviant ones); and (2) the response type (key press for deviant stimuli, no key press for frequent ones). This coding allowed us to compute different averages of ERP target stimuli. These averages were computed for each subject individually. Data were filtered with a 30-Hz low-pass filter.

Table 1
Behavioural results: reaction times (ms) (S.D.)

	Rare happy faces	Rare fearful faces
Behavioural data		
High anxious subjects	413 (48, 74)	390 (50, 18)
Low anxious subjects	454 (39, 29)	424 (39, 28)

Each ERP component (N100, P100, N170, VPP, N300) was manually identified on the basis of its latency range, topographical distribution and reproducibility from the channels Oz, O1, O2, Cz, C3, C4, Pz, P3, P4, P7, P8, Fz, F3, F4, F7, F8 from waveforms evoked by deviant happy and fearful stimuli. The windows for peak detection were included between 90 and 120 ms for N100 and P100, between 140 and 200 ms for N170 and VPP, and between 250 and 350 ms for N300. For N2b (peaking between 200 and 300 ms) and P3b (peaking around 450 ms) components, individual peak amplitudes and individual maximum amplitudes and peak latencies were obtained separately for ERPs resulting from deviant minus standard subtraction. Statistical analyses were computed with SPSS 12.0[®]. The values were tested using ANOVAs. Paired Student *t*-tests were also used when appropriate.

Behavioural data are presented in Table 1. The performance was at 98% correct, and we computed a 2×2 ANOVA with the type of emotion (fear or happiness) as within factor and anxiety level (high or low) as between factor only on correct response latencies.

We observed a main effect of emotion ($F(1,18) = 142.697$; $P < 0.001$): FEAR stimuli are detected faster as compared to HAPPY stimuli in both groups. Moreover, a group effect tendency was observable ($F(1,18) = 3.646$; $P = 0.072$) but no interaction ($F(1,18) = 2.575$; NS). To explore the tendency toward a group effect, paired *t*-tests were computed and showed that HA are quicker than LA subjects when they had to detect rare stimuli, as well for HAPPY stimuli detections ($t(9) = 2.645$; $P = 0.027$) than for FEAR stimuli detections ($t(9) = 2.415$; $P = 0.039$). These results showed a tendency toward a quicker detection of fearful faces as compared to happy faces in all subjects, and a faster detection of deviant stimuli in anxious subjects.

At the ERP level, our first analyses concerned classical early visual waves. For N100 (measured on Cz), P100 (on Oz) and VPP (on Cz), a separate 2×2 ANOVA was applied on midline electrodes with the type of emotion (fear or happiness) as within factor and anxiety level (high or low) as between factor. For N170, which is only recorded at occipito-temporal sites, we should add a laterality factor (P7, P8 electrodes). N100, P100 or VPP were not affected by emotions or anxiety level: this can be interpreted as an absence of any effect of anxiety on perception, whereas a main effect of emotion appeared on N170 amplitude ($F(1,18) = 5.785$; $P = 0.027$): fearful faces elicited enhanced N170 as compared to happy ones. Previous studies showed hemisphere and amplitude modulations with emotion expression on this wave [1,5]. Our observation is in line with the Batty and Taylor's findings [1], who proposed two hypotheses in

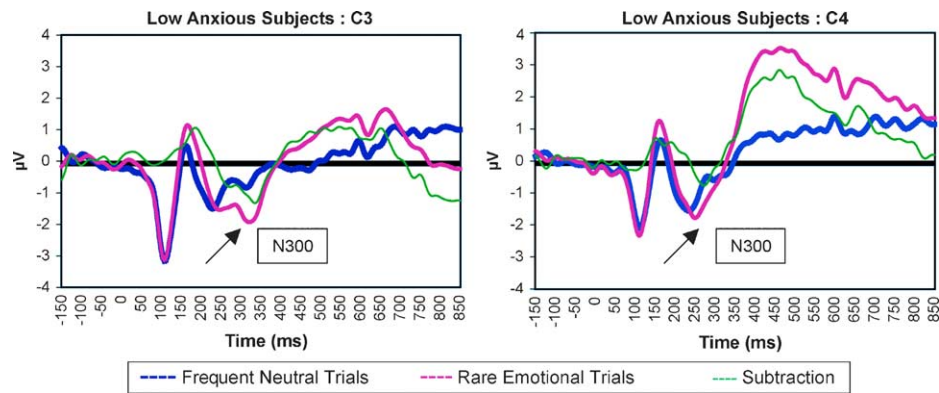


Fig. 1. Grand averages obtained from the 10 low anxious subjects, in each of the two channels (C3 and C4) in response to the two groups of stimuli (neutral vs. emotional faces).

order to explain it. First, fear processing may imply more important underlying neuronal network. Second, increased N170 amplitude for fear may be the result of unconscious mobilization of attention, with an enhancement of perceptual process.

N300 waves are illustrated by Figs. 1 and 2. Since N300 component has been described to react more to affective features of stimuli than to physical characteristics, we first checked whether we obtained a larger N300 for emotional stimuli than for neutral ones in control subjects. The 2 (valence: neutral or emotional) \times 2 (laterality) ANOVA performed on mean amplitude of the N300 component in the 10 low-anxious subjects only underlined a larger N300 for emotional trials compared to neutral ones ($F(1,9)=9.502$; $P=0.013$). We thus highlight the presence of a significant N300 for emotional stimuli compared to the neutral ones in our LA subjects, as showed by Fig. 1. A 2 (emotion) \times 2 (hemisphere) \times 2 (group) ANOVA revealed a main effect

of emotion, both on latency ($F(1,18)=4.804$; $P=0.042$) and amplitude ($F(1,18)=9.054$; $P=0.008$). The hemisphere effect was significant on amplitude only ($F(1,18)=9.340$; $P=0.007$): N300 is larger for fear trials than for happy ones, and enhanced over the left hemisphere. Due to the small number of participants, group effect was not significant ($F(1,18)=3.019$; $P=0.099$), but if we calculate partial Eta squared, which gives the part of total variability explained by the chosen factor, we obtain a figure of 14.4%. In order to explore the tendency toward group effect, t -tests showed a significant difference on C4, as on happy trials ($t(9)=-5.373$; $P>0.001$) as on fear trials ($t(9)=-2.87$; $P=0.018$): HA produced a reduced N300 to emotion compared to LA on the right hemisphere, known to be especially sensitive to the emotionality of a face and particularly implicated in the processing of negative emotions, while positive emotions are localized within the left hemisphere [10].

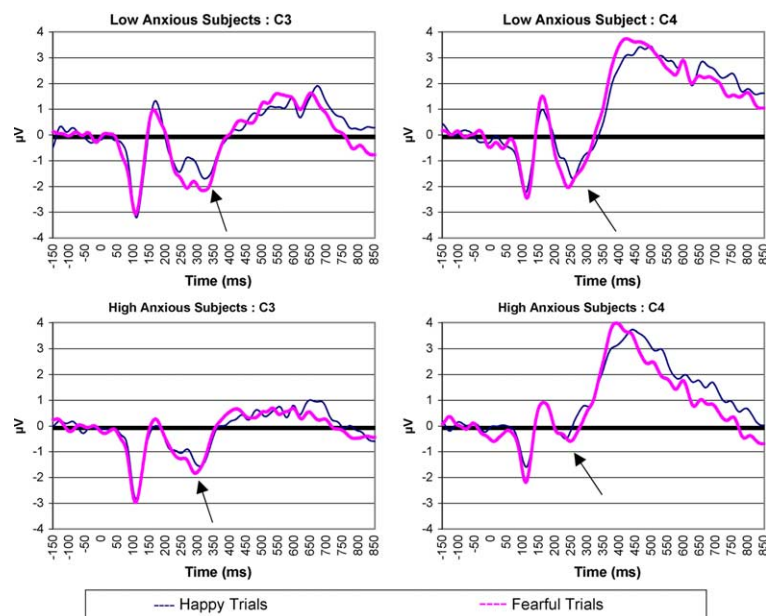


Fig. 2. N300 elicited by happy and fearful faces (grand averages), in low and high anxious subjects, in each of the two channels (C3 and C4).

Table 2
Classical (direct measures) and oddball waves (subtraction between frequent and rare-happy trials and between frequent and rare-happy trials)

	Rare happy faces		Rare fearful faces	
	Latencies	Amplitudes	Latencies	Amplitudes
N2b (O1)				
HA subjects	245 (38.97)	−3.66 (1.9)	232 (28.54)	3.95 (2.5)
LA subjects	247 (29.41)	−5.19 (1.94)	221 (34.94)	−4.33 (1.95)
N2b (O2)				
HA subjects	242 (39.58)	−3.96 (1.71)	235 (26.61)	−4.48 (2.3)
LA subjects	244 (29.63)	−4.33 (1.9)	217 (22.31)	−4.73 (2.22)
P3b (P3)				
HA subjects	410 (35.9)	5.58 (2.56)	418 (28.38)	6.4 (2.27)
LA subjects	457 (15.98)	5.88 (2.55)	427 (26.84)	7.38 (3.19)
P3b (P4)				
HA subjects	422 (36.36)	6.59 (3.48)	404 (27.68)	6.82 (3.15)
LA subjects	458 (38.71)	6.28 (2.41)	445 (26.81)	7.34 (3.49)

Latencies (ms) and amplitudes (μV) (S.D.).

Table 2 shows latency and amplitude values for N2b and P3b, obtained by the subtraction of ERPs obtained in response to frequent stimuli from those obtained in response to the deviant ones. ANOVA $2 \times 2 \times 2$ were computed, with emotion and laterality as within factors, and group as between factor.

ANOVA discloses a significant main effect of emotion on N2b latency ($F(1,18) = 9.99$; $P = 0.005$): fear evoked earlier N2b peak than happiness, without group difference. Emotions do not affect the amplitude of N2b, but an interaction effect ($F(1,18) = 5.851$; $P = 0.026$) can be observed: N2b was maximally recorded on the left side for rare happy face, and on the right side for rare fearful face. This result is in agreement with the Fox's observation, which proposed that right hemisphere could be particularly sensitive to the presence of a fear-relevant stimuli in anxious individuals [10].²

P3b analysis discloses main emotion effect both in latency ($F(1,18) = 6.31$; $P = 0.022$) and in amplitude ($F(1,18) = 10.11$; $P = 0.005$) showing, for both groups, earlier latency and higher amplitude for P3b component in response to fear trials than to happy ones. Analysis also reveals a main effect of group on P3b latency ($F(1,18) = 9.015$; $P = 0.008$): P3b appears earlier in HA subjects, *both for happy and fearful trials*. Moreover, ANOVA discloses a group \times laterality \times emotion interaction ($F(1,18) = 8.81$; $P = 0.008$). This interaction indicates that, in HA subjects, P3b appeared earlier for fear trials on the right side, whereas happiness evokes quicker P3b on the left side. In low anxious subjects, fear bilaterally evokes shorter P3b latencies.

The first important result is that *fear is detected before happiness*, without influence of anxiety level. As already suggested [6,8], negative events seem to be correlated with faster

responses, regardless of the presence of anxiety, in order to prepare us to escape or to confront with a possible danger.

This behavioural effect is neurophysiologically indexed as follows. First, the N2b component, reflecting the degree of attention carried to the visual data processing, shows earlier latency for fearful stimuli, indicating that greater attentional resources are devoted to fearful face detection. Second, the P3b component, associated with various processes such as decision-making and pre-motor response preparation, is both enhanced in amplitude and of shorter latency for fearful stimuli. This reflects a faster response-related stage, originating in greater attentional resources (N2b) allocated to fearful stimuli. This is consistent with previous studies showing, for instance, that fearful faces elicits an orienting of visual attention towards their location [17].

However, Campanella et al. [6] pointed to the fact that the physical differences between neutral and fearful faces are more important than the differences between neutral and happy faces. As a consequence, subjects could detect more quickly the physical differences linked to the expression of fear, without fully processing the emotional characteristics of the stimuli. It is the reason of our interest for N300. A clue in favour of a general superior fear processing is our observation that N300 was enhanced in amplitude for fearful stimuli, as well for LA than for HA subjects. Schutter et al. [18] already showed an enhanced N300 for angry facial expression, attributed to a more elaborated evaluation of the relevant stimuli, and N300 has been related to the arousal of the stimuli [18]. So, it seems that fearful face possesses a comparable arousal valence as anger.

The second result relates to the *effect of anxiety on the emotional information processing*. Anxious subjects were faster than controls in the detection of rare stimuli, independently of their valence. We suggest that high anxiety level increases the vigilance of the subjects, and elicits a general enhanced emotional processing. Bradley et al. [3] already found that generalized anxious patients were more vigilant for emotional faces in general, and not only towards threatening faces. Two alternative explanations were proposed: on the one hand, happy faces might be interpreted as threatening by anxious people, as an approach signal or a sign of mockery. On the other hand, anxious subjects could strategically allocate their attention to pleasant stimuli in order to reduce aversive state elicited by threat stimuli. The main interest of our study is to define the neurophysiological correlates of this general enhanced processing. Its origin does not seem to be of an attentional nature, since we show that subjects do not differ on attentional resources allocated to the stimuli (no effect of group on the N2b component). However, the modification of emotional processing begins during the specific evaluation of emotions: even if LA and HA subjects both showed larger N300 for fearful stimuli, HA subjects showed a general reduction in N300 amplitude on the right side compared to LA subjects, in response to both happiness and fear stimuli (see Fig. 2). Accordingly, in current literature, weaker amplitudes reflect shallower processing [4]. N300 has been described as

² In the present study, we do not expect P3a modulations because all rare stimuli have the same probability of occurrence, sharing then the same level of "novelty" among the train of standard stimuli. As a consequence, only N2b results will be reported in the present study.

more responding to emotional value attributed to stimuli by subjects, than to physical and configurational characteristics [7]. Then, our results suggest that HA subjects are less responsive to the emotional content of fearful and happy faces.

Nevertheless, despite a worse emotional processing indexed by a decreased N300 component, the P3b latency appears *significantly earlier* in the HA participants. In his review, Hansenne [12] recalls the important influence of vigilance and arousal on P300, and its frequent alterations in psychopathology. However, we are not aware of any study investigating P3b on non-clinical anxious subjects. We interpret this effect of anxiety on P3b as a way to overcome the deficient emotional appraisal (on N300), leading to a more salient conscious processing.

To summarize, normal subjects with anxious tendencies display a faster detection of deviant stimuli. This processing does not diverge from that of the LA-control subjects on the level of the basic analysis of the face-stimulus (P100, N100, N170, VPP) or on the attentional resources allocated to the task (N2b), but on the management of the emotional load of the stimulus (N300), and the decision-making process of answer-preparation (P3b). Consequently, we propose that the HA subjects allocate less resources with the direct evaluation of the emotionality of the stimuli (decreased N300), but would carry out an increased conscious treatment, associated to an accelerated decision-making, appearing on P3b.

An important point to outline is that our groups were created on the basis of subjects' score on Spielberger Trait Anxiety Inventory, for which they were clearly contrasted, but we did not consider the State dimension of anxiety. Consequently, the authors having insisted on the importance of the congruence of the scores on the two dimensions of scales measuring anxiety level [8,10], it would be useful to control in further studies that both HA and LA groups were characterized by congruent state and trait-anxiety scores.

Other studies have been conducted using ERP in anxiety [8,20]. Nonetheless, to our knowledge, our study is the first one trying to clarify the processing of emotional faces-stimuli in anxious subjects, using an emotional oddball paradigm. Further studies should confirm these preliminary data, and control the specific emotional nature of the modulated processing in HA subjects.

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