## Première question de recherche

Ainsi que formulé précédemment, l'objectif de notre première étude visait à étudier les corrélats électrophysiologiques sous-tendant la perception de visages neutres et émotionnels chez des sujets souffrant d'anxiété sous-clinique. Dans cette optique, nous avons conçu une étude basée sur un paradigme de détection de déviance, parce que ce design expérimental offrait les avantages d'avoir été largement utilisé (voir par exemple Bange & Bathien, 1998; Campanella et al., 2002a; Campanella, Rossignol, Mejias, Joassin, Maurage, Debatisse, Bruyer, Crommelinck & Guérit, 2004; Susac, Ilmoniemi, Pihko & Supek, 2004), au point d'offrir une littérature foisonnante concernant les sujets contrôles et de permettre l'examen d'ondes bien définies dont l'origine et les fonctions sont relativement peu controversées. Nous avons également choisi d'utiliser dans un premier temps des émotions peu sujettes à polémiques, à savoir des expressions de peur et de joie, à détecter parmi des visages neutres. Le choix de ces émotions se justifie à la fois par la pertinence de la peur dans l'anxiété, comme abondamment discuté dans les pages précédentes, et par la position particulière de la joie comme seule émotion réellement positive dans la classification d'Ekman, et comme émotion de valence positive et d'intensité élevée dans le modèle bidimensionnel.

Cette première étude ne manquait cependant pas d'ambition, puisqu'en l'absence de références, nous nous attendions à observer le biais de traitement en faveur des EFE de peur si largement rapporté dans la littérature relative à l'anxiété. Nous avions en outre pour objectif de corréler ce biais à une étape

particulière du traitement visuel, à savoir l'étape perceptive générale (composant N100/P100) ou propre aux visages (composant N170/VPP), l'étape attentionnelle (composant N2b/P3a), ou encore l'étape décisionnelle (composant P3b), sans oublier l'examen de cette étape particulière décrite notamment par Carretié et correspondant à un traitement affectif (composant N300). Le chapitre 4 décrira cette première recherche, alors que le chapitre 5 se centrera sur une étude de conception similaire, mais étendant le questionnement à d'autres émotions négatives comme la colère ou le dégoût, et investiguera des sujets souffrant d'anxiété sociale afin de pouvoir comparer les déficits observables dans ces deux désordres et de tenter de les placer sur un même continuum ou sur deux continuums différents.

# Chapitre 4 :

# Influence de l'anxiété-trait sur la détection d'expressions faciales de joie et de peur

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Rossignol, M., Philippot, P., Douilliez, C., Crommelinck, M., & Campanella, S. (2005). The perception of fearful and happy facial expression is modulated by anxiety: an event-related potential study. Neuroscience Letters, 377(2), 115-120.

## 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 & 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.

## 1. Introduction

Different lines of evidence suggest that anxiety interferes with emotion processing in such a way that anxious subjects are particularly sensitive to threatening information (Fox, 2002; Mogg & Bradley, 2002; Weinstein, 1995), and show, for instance, a processing bias towards threat-related facial expressions (Fox, 2002; Weinstein, 1995). 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 (Mathews & MacLeod, 1994): For instance, vigilance is biased towards physical threat in panic disorders, towards socially threatening situations in socially anxious (Mogg & Bradley, 2002), and towards their idiosyncratic worries in generalized anxious people (Mathews & MacLeod, 1994). In the present study, we will focus on normal subjects showing anxious tendencies, because some studies have already suggested the presence of a bias towards threatening information in sub-clinically anxious people (Carretié et al., 2004b; Mogg et al., 1997; Weinstein, 1995) with verbal material. To our knowledge, only one study has addressed whether sub-clinical anxiety elicits, as in clinical conditions, a bias towards threatening visual material, and more specifically, towards visual emotional facial expressions (Fox, 2002). 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 (Fox, 2002; Pourtois et al., 2004). 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 (Morris et al., 1996; Pourtois et al., 2004). At the same time, 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 (Fox, 2002). Therefore, studying the role of such a bias in the aetiology and persistence of anxiety has revealed to be of the greatest relevance (Mogg & Bradley, 2002). 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 (Mathews & MacLeod, 1994). Surprisingly, Bradley and Mogg (1999) 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 expressions of fear and joy. Event-related potentials 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 (Campanella et al., 2002a). 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 250ms, and its positive counterpart at frontal sites called the P3a. The N2/P3a complex is known as a bipolar "attentional orienting complex" (Campanella et al., 2002a; Halgren & Marinkovic, 1995). The N2b component refers to the attention switch needed to take a new information into account (Suwazono et al., 2000), and the P3a component is sensitive to the degree of novelty of the deviant information (Knight, 1991). Second, the P3b component, peaking at parietal sites around 450ms. This positive wave arises when an attended stimulus is detected , and should reflect decision making and premotor response-related stages (Bentin et al., 1999; Hansenne, 2000a; Polich, 2004). 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 300ms at central

sites, is supposed to be particularly sensitive to emotional stimulation (Carretié & Iglesias, 1995). N300 would reflect an affective processing and is few affected by cognition, in such a way that it reacts more to affective features of stimuli rather than to physical characteristics (Carretié & Iglesias, 1995; Carretié et al., 1997b). For instance, Schutter, de Haan and van Honk (2004) have related N300 to the arousal of the stimuli, 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 & Tenke, 1999).

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. Then, two components are usually considered as face-specific: the bilateral N170 recorded at occipito-temporal sites (Bentin et al., 1996) and its positive counterpart at Cz called the Vertex Positive Potential (VPP, Bötzel & Grüsser, 1989). N170 has been described as unaffected by facial expressions (Eimer & Holmes, 2002), but some studies showed N170 modulations with valence of visually presented emotions (Batty & Taylor, 2003; Campanella et al., 2002b).

Consequently, the study of the different ERP component evoked in response to proposed stimuli should give more information about the processing of emotional visual information in the subjects, and allow to define more precisely the level of occurrence of the processing bias in anxiety.

We pose the assumption 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 the 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.

## 2. Methods

### 2.1. Participants

Twenty participants (right-handed, with normal/corrected vision, and without neurological disease) were selected based on their score on the Spielberger State and Trait Anxiety Inventory (STAI, Spielberger et al., 1983) and 13-items Beck Inventory Scale (Beck & Beamesdefer, 1974) among 128 University of Louvain students.

The distinction between high and low anxious was made by median splits on standardised measure of anxiety (STAI-T : median = 50[10]), and we chose students with similar scores on the Beck Inventory Scale to create two original groups. Ten students were grouped as low-anxious (LA), and ten as high-anxious (HA). Both groups comported 8 female and 2 male participants.

The 13-items Beck Inventory Scale (Beck & Beamesdefer, 1974) was also completed by subjects, as depression covariates with anxiety and affects EFE perception (Mathews & MacLeod, 1994) and we checked that groups were not depressed (general mean: 4.5; SD: 3.56), and not contrasted neither on Beck Score ($t(9)$=-1.983 ; N.S.) nor on age ($t(9)$=.061; N.S.), but differed on state and trait anxiety level (respectively, $t(9)$=-2.796 ; $p$=.021 ; and $t(9)$=-6.638 ; $p$>.001). Groups characteristics are reported in Table 1.

[10] 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.

**Table 1 : Mean scores (and standard deviations) for questionnaire measures of State-Anxiety (STAI-A), Trait-Anxiety (STAI-B), and Depression (Beck).**

| | Age | STAI-A | STAI-B | Beck |
|---|---|---|---|---|
| **Low Trait Anxiety Group (N=10)** | 22.4 (4.14) | 46.4 (8.55) | 38.9 (7.14) | 5.1 (3.1) |
| **High Trait Anxiety Group (N=10)** | 22.3 (2.58) | 54.8 (10.71) | 59.7 (5.06) | 3.0 (2.9) |

### 2.2. Material and procedure

The experimental design follows an oddball paradigm. Stimuli consisted in four faces (selected from highly standardized set of pictures of Ekman & Friesen series, Ekman & Friesen, 1976; 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 faces A happy, and 8 deviant faces 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 X 4° 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 kΩ. 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.

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 90-120 ms for N100 and P100, between 140-200 ms for N170 and VPP, and between 250-350 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 Statistical Package for Social Sciences, 12$^{th}$ version (SPSS 12.0®). The values were tested using ANOVAs. Paired Student *t*-tests were also used when appropriate.

## 3. Results

### 3.1. Behavioral results

Behavioural data are presented in Table 2. The performance was at 98% correct, and we computed a 2x2 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.

**Table 2 : Behavioural results : Reaction times (ms) (S.D.).**

| | **Rare happy faces** | **Rare fearful faces** |
|---|---|---|
| **Low Trait Anxiety Group** | 413 (48,74) | 390 (50,18) |
| **High Trait Anxiety Group** | 454 (39,29) | 424 (39,28) |

We observed a main effect of emotion ($F(1,18) = 142.697$ ; $p < .001$): FEAR stimuli are detected faster as compared to HAPPY stimuli in both groups. Moreover, a group effect tendency was observable ($F(1,18) = 3.646$ ; $p = .072$) but no interaction ($F(1, 18) = 2.575$ ; N.S.) . 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 ($t(9) = 2.645$; $p = .027$) than for FEAR stimuli detections ($t(9) = 2.415$; $p = .039$). 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.

### 3.2. Electrophysiological data

At the ERP level, our first analyses concerned classical early visual waves (see table 2). For N100 (measured on Cz), P100 (on Oz) and VPP (on Cz), a separate 2x2 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 ($F(1, 18)= 5.785$ ; $p=.027$) : fearful faces elicited enhanced N170 as compared to happy ones. Previous studies showed hemisphere and amplitude modulations with emotion expression on this wave (Batty & Taylor, 2003). Our observation is in line with the Batty and Taylor's findings (2003), who proposed two hypotheses in 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 mobilisation of attention, with an enhancement of perceptual process.

N300 waves are illustrated by Figure 16 and Figure 17. Since N300 component has been described to react more to affective features of stimuli than to physical characteristics, we firstly checked if we obtained a larger N300 for emotional stimuli than for neutral ones in control subjects. The 2 (valence: neutral or emotional) x 2 (laterality) ANOVA performed on mean amplitude of N300 component in the 10 low-anxious subjects only underlined

a larger N300 for emotional trials compared to neutral ones ($F(1,9) = 9.502$ ; $p = .013$).

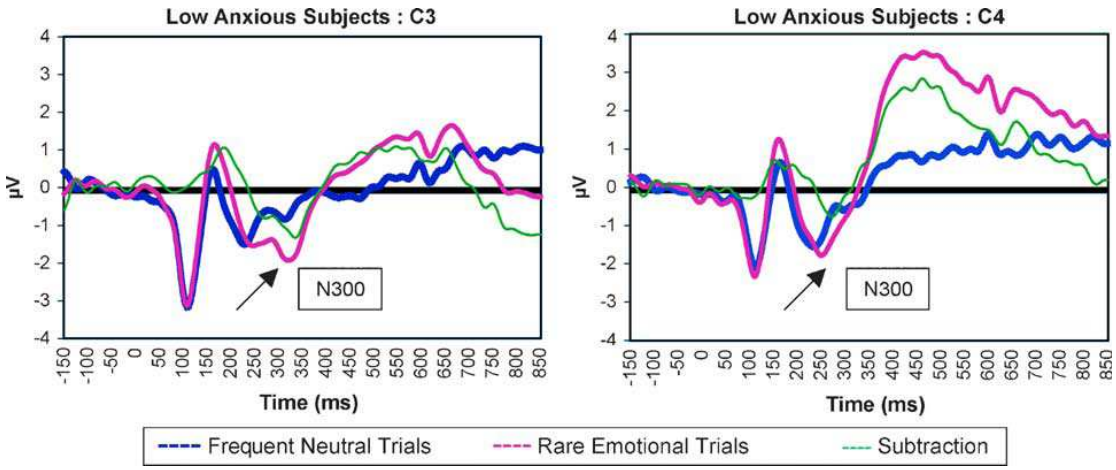


**Figure 16 : Grand averages obtained from the 10 low anxious subjects, in each of the two channels (C3 and C4) in response to the two groups of stimuli (neutral vs. emotional faces).**

We thus highlight the presence of a significant N300 for emotional stimuli compared to the neutral ones in our LA subjects, as showed by Figure 16. A two (emotion) by two (hemisphere) by two (group) ANOVA revealed a main effect of emotion, both on latency ($F(1,18) = 4.804$ ; $p = .042$) and amplitude ($F(1,18) = 9.054$ ; $p = .008$). The hemisphere effect was significant on amplitude only ($F(1,18) = 9.340$ ; $p = .007$): 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 ($F(1,18) = 3.019$ ; $p = .099$), 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 ($t(9) = -5.373$ ; $p > .001$) as on

fear trials ($t(9)$= -2.87 ; $p$=.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 (Fox, 2002).

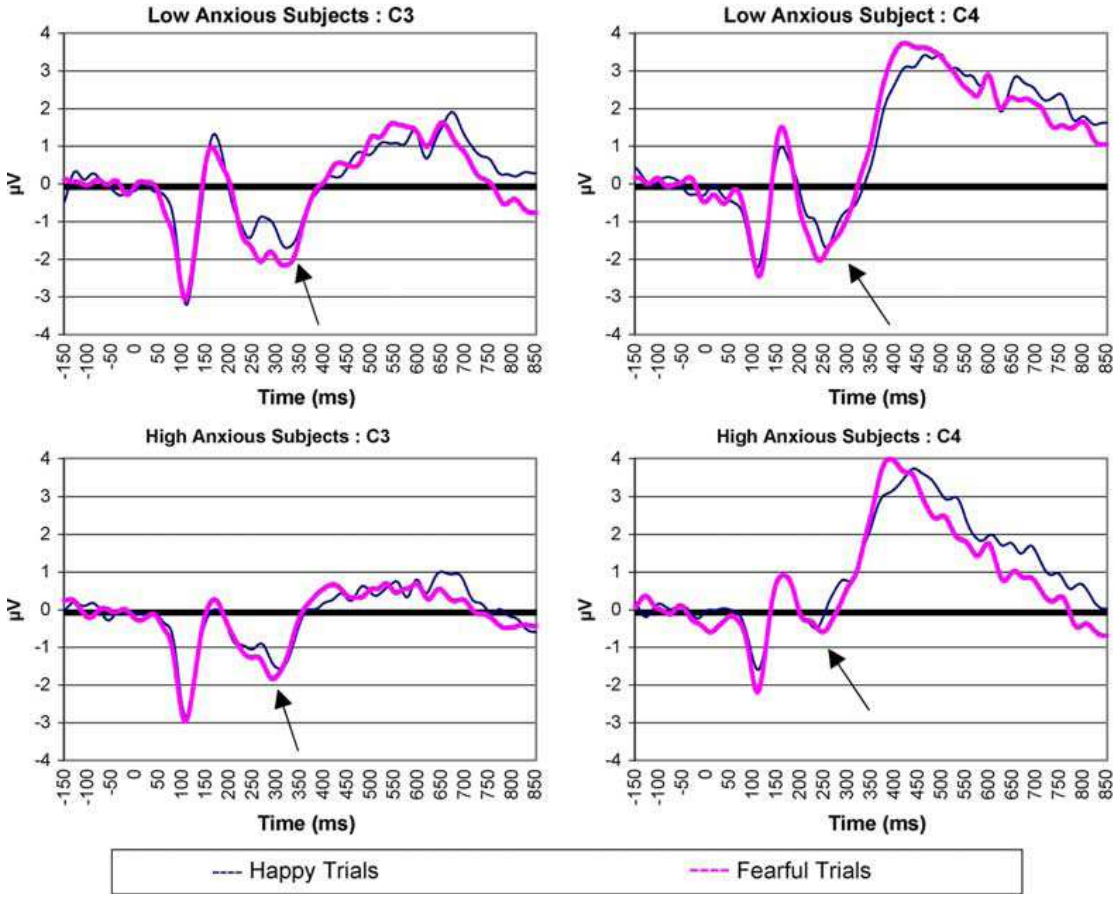


**Figure 17 : N300 elicited by happy and fearful faces (grand averages), in low and high anxious subjects, in each of the two channels (C3 and C4).**

Table 3 shows latency and amplitude values for N2b and P3b[11], obtained by the subtraction of ERPs obtained in response to frequent stimuli from those obtained in response to the deviant ones. ANOVA 2x2x2 were computed, with emotion and laterality as within factors, and group as between factor.

**Table 3 : Classical (direct measures) and Oddball waves (subtraction between frequent and rare-fearful trials and between frequent and rare-happy trials); latencies (ms) and amplitudes (µV) (S.D.).**

| | Neutral Faces | | Rare Happy Faces | | Rare Fearful Faces | |
|---|---|---|---|---|---|---|
| | **Latencies** | **Amplitudes** | **Latencies** | **Amplitudes** | **Latencies** | **Amplitudes** |
| **P100 (Oz)** | | | | | | |
| HA | 117 (17.65) | 8.97 (3.46) | 112 (12.55) | 8.65 (2.71) | 114 (19.76) | 9.28 (3.29) |
| LA | 113 (8.44) | 8.84 (4.67) | 109 (8.089) | 8.81 (4.44) | 114 (12.02) | 8.31 (4.52) |
| **N100 (Cz)** | | | | | | |
| HA | 109 (9.34) | -4.6 (1.71) | 107 (8.21) | -4.01 (1.92) | 108 (10.68) | -4.79 (1.87) |
| LA | 108 (8.04) | -5.11 (1.7) | 107 (6.8) | -5.23 (2.28) | 108 (8.62) | -5.10 (1.94) |
| **VPP (Cz)** | | | | | | |
| HA | 159 (14.58) | 0.96 (1.74) | 160 (12.65) | 2.19 (2.19) | 165 (17.74) | 2.48 (1.82) |
| LA | 159 (10.3) | 1.92 (2.13) | 164 (13.56) | 2.92 (1.96) | 162 (14.09) | 3.03 (2.86) |
| **N170 (P7)** | | | | | | |
| HA | 153 (9.92) | -1.88 (3.09) | 153 (10.05) | -3.29 (1.9) | 153 (8.68) | -3.71 (2.68) |
| LA | 158 (10.55) | -3.25 (2.87) | 160 (12.02) | -4.46 (3.27) | 162 (13.56) | -5.34 (3.73) |
| **N170 (P8)** | | | | | | |
| HA | 155 (10.55) | -1.7 (2.66) | 163 (16.63) | -2.49 (2.65) | 170 (28.19) | -2.49 (2.34) |
| LA | 156 (8.59) | -2.63 (2.98) | 160 (8.76) | -4.09 (2.92) | 165 (18.26) | -5.11 (3.84) |
| **N2b (O1)** | | | | | | |
| HA | | | 245 (38.97) | -3.66 (1.9) | 232 (28.54) | 3.95 (2.5) |
| LA | | | 247 (29.41) | -5.19 (1.94) | 221 (34.94) | -4.33 (1.95) |
| **N2b (O2)** | | | | | | |
| HA | | | 242 (39.58) | -3.96 (1.71) | 235 (26.61) | -4.48 (2.3) |
| LA | | | 244 (29.63) | -4.33 (1.9) | 217 (22.31) | -4.73 (2.22) |
| **P3b (P3)** | | | | | | |
| HA | | | 410 (35.9) | 5.58 (2.56) | 418 (28.38) | 6.4 (2.27) |
| LA | | | 457 (15.98) | 5.88 (2.55) | 427 (26.84) | 7.38 (3.19) |
| **P3b (P4)** | | | | | | |
| HA | | | 422 (36.36) | 6.59 (3.48) | 404 (27.68) | 6.82 (3.15) |
| LA | | | 458 (38.71) | 6.28 (2.41) | 445 (26.81) | 7.34 (3.49) |

[11] 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.

ANOVA discloses a significant main effect of emotion on N2b latency ($F(1,18) = 9.99$ ; $p=.005$) : fear evoked earlier N2b peak than happiness, without group difference. Emotions do not affect the amplitude of N2b, but an interaction effect ($F(1,18) = 5.851$ ; $p=.026$) 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 (Fox, 2002).

P3b analysis discloses main emotion effect both in latency ($F(1,18) = 6.31$ ; $p=.022$) and in amplitude ($F(1,18) = 10.11$ ; $p=.005$) 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 ($F(1,18) = 9.\ 015$ ; $p=.008$) : P3b appears earlier in HA subjects, both for happy and fearful trials. Moreover, ANOVA discloses a group x laterality x emotion interaction ($F(1,18) = 8.81$ ; $p=.008$). 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.

## 4. Discussion

The first important result is that fear is detected before happiness, without influence of anxiety level. As already suggested (Campanella et al., 2004; Carretié et al., 2004b), 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 the 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 (Pourtois et al., 2004).

However, Campanella et al. (2004) 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. (2004) 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. So, it seems that fearful face possesses a comparable arousal valence as anger.

The second result relates to the effect of the 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. (1999) 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 Figure 17). Accordingly, in current literature, weaker amplitudes reflect shallower processing (Cardenas, Chao, Blumenfeld, Song, Meyerhoff, Weiner & Studholme, 2005). N300 has been described as more responding to emotional value attributed to stimuli by subjects, than to physical and configurational characteristics (Carretié & Iglesias, 1995). 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 (2000b) 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, the 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, even if these preliminary results should be confirmed, 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 LA group obtains low scores on the 'trait' anxiety scale, but normal score on the 'state' scale. This can be explained by a certain discomfort related to the testing situation but, the authors having insisted on the importance of the congruence of the scores on the two scales (Carretié et al., 2004b; Fox, 2002), it would be useful to control in further studies that the control group obtains similar weak scores on the two scales of anxiety.

Other studies have been conducted using ERP in anxiety (Carretié et al., 2004b; Weinstein, 1995). 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.

# Chapitre 5 :

# Impact de l'anxiété sociale sur la détection des expressions faciales émotionnelles

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Rossignol, M., Campanella, S., Falbo, L. and Philippot, P. Visual processing of emotional facial expressions in social anxiety: An event-related potentials study. Clinical Neurophysiology, Soumis.

## Abstract

Negative facial expressions constitute socially threatening stimuli that are particularly important signals to process as they often warn off the potential presence of a danger in the environment. Conversely, selective attention towards threat might be specially enhanced in anxiety and more specifically in social anxiety, since that pathology has been characterized by abnormal processing of social information. This study investigated the influence of social anxiety on the event-related potentials (ERPs) correlates of emotional faces detection. Participants reporting high or low social anxiety were presented with a visual oddball paradigm, in which they had to detect rare emotional stimuli displaying disgust, happiness, fear or anger amongst frequent neutral faces. Socially anxious participants were not faster to detect deviant faces, but they displayed enhanced N100/P100 complex in response to rare faces. Additionally, they demonstrated faster N300 in response to anger and disgust, whilst low socially anxious individuals produced earlier waves in response to neutral or positive faces. These results suggest an increased perceptual vigilance to faces in social anxiety and a modulation of the emotional appraisal stage. Moreover, rare emotional stimuli elicited enhanced perceptual responses, followed by a differential appraisal of emotional faces indexed by delayed N300 for negative emotions, particularly for fear and anger. These two latter emotions also evoked delayed P300 component and later response latencies. These delayed responses to most threatening expressions might be attributable to the division of attentional resources required by the detection of several types of negative deviant stimuli.

## 1. Introduction

Negative facial expressions constitute socially threatening stimuli that are particularly important signals to process as they often warn off the potential presence of a danger in the environment. Many studies have shown that fearful faces are processed in an automatic and unconscious way and that this processing is mainly sustained by the activation of the amygdala (Morris et al., 1996; Pourtois et al., 2004). However, selective attention towards threat might be specially enhanced in anxiety and more specifically in social anxiety, since that pathology has been characterized by abnormal processing of social information (Rapee & Heimberg, 1997). The hypothesis of a hypervigilance towards threat has been investigated with a particular interest for generalized anxiety disorders and social anxiety and their sub-clinical forms (Mogg & Bradley, 2004). While generalized and trait anxiety are characterized by increased arousal and hypervigilance in every-day life, social anxiety is the fear of social situations and of interactions with other people, implying self-consciousness, judgment, evaluation, and feeling of inferiority. Consequently, attentional resources of social anxious people are mainly concentrated towards stimuli that may elicit negative evaluation (Marcin & Nemeroff, 2003).

In this perspective, several authors have postulated a bias in the perception of emotional facial expressions in anxiety disorders, with a special interest for anger and fear detection (Fox, 2002; Fox et al., 2000; Garner et al., 2006; Mogg & Bradley, 2002; Mogg et al., 2004). These studies have often been based on the dot-probe paradigm, inspired from Posner and colleagues'

research (Posner & Petersen, 1990; Posner et al., 1980), which gives a good index of attention: pairs of faces are typically presented during 500 or 1250 ms, and a dot replaces one of the two face locations after their disappearance. Each pair is constituted by a neutral face and an emotional one (threatening or smiling). Classical studies on healthy participants have shown that people are faster to respond to a probe stimulus presented in an attended region of a visual display (Posner et al., 1980). Consequently, if anxious subjects are more vigilant to visual threat, they should respond faster when probes replace threatening faces rather than positive or neutral ones.

On the one hand, behavioral studies have showed that individuals with high social anxiety were faster to respond to probes occurring in the spatial location of threat rather than neutral faces(Mogg & Bradley, 1999a, 2002; Mogg et al., 2004). Moreover, this effect also occurs for masked-faces presentation, as the subjects' attention is automatically captured by subthreshold threat cues. Further analysis demonstrated that this vigilance effect for masked threat faces appears to be primarily a function of social anxiety and social avoidance, rather than a trait anxiety indexing a more generalized disorder (Mogg & Bradley, 2002).

On the other hand, studies on generalized anxiety disorder have demonstrated a similar bias towards threatening information in GAD patients. For instance, Mogg et al. (2000b) used different emotions (threatening, sad, happy, and neutral faces presented for 1,000 ms) in a probe detection task to test GAD and depressed individuals. Results showed that, as in social anxiety, individuals with GAD without depressive disorder were

more likely to first look toward threatening faces rather than to neutral faces, and shifted their gaze more quickly toward threatening faces, rather than away from them, compared with normal controls. Non-clinical high anxious individuals also seem more vigilant for fearful faces and avoidant of happy faces appearing in left visual field (Fox, 2002), consistent with the finding that an increased vigilance of the right hemisphere for fear-relevant stimuli (Mogg & Bradley, 2002). However, social anxiety and trait anxiety have not been related to explicit biases when subjects have to rate positive or negative faces (Cooper et al., 2008; Philippot & Douilliez, 2005).

In conclusion, behavioral studies demonstrated attentional biases towards threatening -angry and fearful- facial expressions in anxiety. However, the neurophysiological correlates of these biases have not been clearly evidenced hitherto. Yet, the excellent temporal resolution of ERPs enables to precisely index the time courses of affective processing (Olofsson et al., 2008), and it has been shown that threat perception modulates cognitive processing as soon as 100ms after stimulus occurrence (Batty & Taylor, 2003; Pourtois et al., 2004) and until closure mechanisms (Campanella et al., 2002a). In the general population, the presence of vigilance biases towards emotions has been associated with the alteration of several ERP components in paradigms using pictures or words (Carretié, Mercado, Tapia & Hinojosa, 2001b; Weinstein, 1995). ERPs could thus be used to index temporal parameters of attentional biases in anxiety. Yet, surprisingly few studies have investigated electrophysiological correlates of emotional face processing in anxiety, and have moreover reported conflicting findings. For instance, high

trait anxiety has been associated with higher amplitudes of P100 component in response to fear (Holmes et al., 2008), and with earlier N100/P100 for angry, fearful, sad, and happy faces (Bar-Haim et al., 2005). Social anxiety has also been related to an enhanced P100 in individuals with social phobia, as with an increased N170 when these participants had to identify the emotion displayed by angry faces (Kolassa & Miltner, 2006). These results suggest greater mobilization of attentional resources in high trait or social anxiety. However, other studies have failed to replicate these findings (Rossignol, Philippot, Crommelinck & Campanella, 2008; Rossignol, Philippot, Douilliez, Crommelinck & Campanella, 2005). Concerning late components reflecting more conscious processes, some data suggest that social anxiety modulates P300 component, which appeared enhanced for threatening faces (Moser et al., 2008). Other data have reported a correlation between level of social anxiety and peak voltage of P300 for angry but not for happy faces (Sewell et al., 2008). Lately, the Late Positive Potential, assimilated to P300 in studies that do not require specific response, also appears as enhanced for emotional faces perception in sub-clinical social anxiety (Muhlberger et al., 2008). It is important to note that some of theses studies did not investigated early ERP waves. However, if a deficit in P300 is a common finding in psychopathological states (see for instance Hansenne, 2000b), the subjacent deficit may be circumscribed to response-related stages but it also might originate in lower level of processing (e.g. an attentional deficit), and extend to the later processes (see for instance Foxe, Murray & Javitt, 2005; Maurage, Philippot, Verbanck, Noel, Kornreich, Hanak & Campanella, 2007).

Concerning trait anxiety influence on P300 component, in an emotional oddball paradigm in which participants had to detect fearful or happy faces, among neutral faces, Rossignol et al. (2005) observed an earlier P300 for fear and happy faces correlated with faster reaction time in high trait anxiety. The absence of emotional specificity was confirmed in a second study using deviant faces varying on emotional expressions (sadness and happiness) or on identity (Rossignol et al., 2008). Trait-anxiety thus seems associated with late modifications of cognitive processing of emotional stimuli, since earlier components, such as perceptive (N100-P100-N170) or attentional-related (N2b-P3a) waves were not modulated by trait-anxiety.

Furthermore, some data suggest that accelerated decisional process can follow a modulated appraisal of emotional stimuli, indexed by a reduced N300 (Rossignol et al., 2005). That monopolar component, a negative deflexion peaking around 300ms at central sites, is particularly sensitive to emotional stimulation (Carretié & Iglesias, 1995). N300 seems to reflect an affective processing and is little affected by cognition, as it reacts more to affective features of stimuli than to their physical characteristics (Carretié & Iglesias, 1995; Carretié et al., 1997b). The enhancement of N300 for emotional (Rossignol et al., 2005) and angry facial expressions (Schutter et al., 2004) may underline a more elaborated evaluation of the relevant stimuli and relates the production of N300 to the stimuli arousal. In consequence, trait anxiety seems to be associated with a modulated appraisal of emotional load of perceived stimuli, and reduced amplitudes may suggest that few resources are devoted to this process.

To summarize, these ERP studies suggest early and late modulations of emotional processing in anxiety, affecting perceptive, attentional, and closure mechanisms. However, these findings remain conflicting, and the paucity of research about neurophysiological correlates of emotional processing in anxiety contrasts with the amount of behavioral data in this field (Holmes et al., 2008).

For instance, available data do not allow to differentiate mechanisms acting in trait or social anxiety. Though, high trait anxiety is characterized by excessive worry in different domains of daily life, over-excitement and motor tension, while fear is concentrated on social situation in social anxiety (Velardi et al., 2006). Thereby, Mogg and Bradley (2002) have proposed that vigilance for faces would be primarily a function of social anxiety and social avoidance, rather than a function of trait anxiety. This hypothesis is sustained by reports of P100 enhancement for face processing without emotional specificity in social anxiety (Kolassa & Miltner, 2006) but limited to fear in trait-anxiety (Holmes et al., 2008). In summary, social anxiety would more directly affect the process of all type of emotional information convey by a media indexing self-evaluation like faces (Chen et al., 2002), and this bias could be indexed at earlier stage of face information processing. On the other hand, trait anxiety might be associated with early attentional biases for threat exclusively, and general later disturbance in face processing (Rossignol et al., 2008; Rossignol et al., 2005).

Consequently, the aim of the present study was to test whether socially anxious individuals show a similar pattern of processing emotional faces as the

one observed in trait anxiety, with alterations localized at the end of emotional processing and occurring on N300 and P300, or whether the impairment of emotional processing occurs earlier and affects visual perceptive stages. To do this, we replicated the design used in Rossignol and collaborators' study (2005). In addition, different emotional expressions were added as deviant stimuli in order to appreciate the extent and valence of potential emotional biases. Deviant faces displayed anger or fear, since these expressions have been pointed to be particularly relevant in the studies listed above, happiness to provide a positive control, and disgust, since some data have suggested a particular role of that emotion in the etiology and persistence of anxious disorders and specially in social anxiety (Amir et al., 2005; Rossignol, Anselme, Vermeulen, Philippot & Campanella, 2007). If social anxiety is associated to a general impairment for face processing, alteration of ERP components would occur for all face categories, and appear as soon as 100ms after the stimulus onset, when faces are identified (Streit et al., 2000). Conversely, an emotion-specific modulation of selective attention would occur for positive and/or negative emotions on the N170 component (Batty & Taylor, 2003), correlated with a quicker detection of negative stimuli (shorter reaction times and earlier P300) in individuals with social anxiety.

## 2. Materials and methods

### 2.1. Participants

Twenty-four participants were pre-selected based on their score on the Fear of Negative Evaluation questionnaire (FNE, Watson and Friend, 1969), the Liebowitz Social Anxiety Scale (LSAS, Liebowitz, 1987; Yao et al., 1999) and the Spielberger Trait Anxiety Inventory (STAI-B, Spielberger et al., 1983) from a sample of students from the University of Louvain. One participant had to be excluded because of artifacts during ERP recording, so that twenty-three participants remained in the sample. All participants were right-handed, between the ages of 18 and 23 years, with normal/corrected vision, and without neurological disease or depression.

Since our aim was to contrast groups exclusively on social anxiety, we selected participants with normal scores on STAI, and we contrasted our groups according to participant's scores to LSAS[12]. Subjects scoring under 55 were grouped in the Low Social Anxiety group (LSA) and those scoring over 56 were grouped in the High Social Anxiety group (HSA). Participants also completed the 13-items Beck Inventory Scale (Beck & Beamesdefer, 1974), as depression covariates with anxiety and affects EFE perception (Rossignol et al., 2008). Group characteristics are reported in Table 4.

[12] Liebowitz (1987) determined four levels of social phobia according to LSAS scores: 56-65: moderated; 65-80: marked; 80-95: heavy; more than 95: very heavy

**Table 4 : Mean scores (and standard deviations) for questionnaire measures of Trait-Anxiety (STAI-B), Fear of Negative Evaluation (FNE), Social Anxiety (LSAS), and Depression (Beck).**

| | Age | Ratio male/female | STAI-B | FNE | LSAS | Beck |
|---|---|---|---|---|---|---|
| **Low Social Anxiety Group (N=12)** | 19.9 (1.6) | 7/5 | 55.6 (2.0) | 5.2 (4.3) | 29.1 (10.5) | 5.1 (3.1) |
| **High Social Anxiety Group (N=11)** | 19.7 (1.5) | 3/8 | 53.9 (2.6) | 16.45 (3.8) | 79.8 (18.2) | 3.0 (2.9) |

The experimental procedure used an 'emotional oddball paradigm', similar to the one used in Rossignol et al' study (2005) and which had proved to be highly informative in psychopathological populations (Mejias, Rossignol, Debatisse, Streel, Servais, Guérit, Philippot & Campanella, 2005; Vermeulen, Luminet, Cordovil de Sousa & Campanella, 2008; see Campanella & Philippot, 2006 for a review).

The stimuli set comprised 30 grey pictures of six different individuals (3 males and 3 females) each posing neutrality, anger, disgust, happiness and fear, taken from the database elaborated by Beaupre and Hess (2006).

After being trimmed to exclude non-facial contours and hair, each facial stimulus was enclosed within a rectangular frame measuring 4x6cm, subtending a visual angle of 4.7° by 8.5°. Stimuli were presented one by one for 500ms on a black background, with a black screen displayed as an inter-trial interval, lasting randomly between 1300 and 1600 ms. Six blocks were composed, each defined by 108 stimuli (e.g. 84 frequent stimuli with face A neutral; 6 deviant face A with an happy, angry, fearful and disgusted expression) and were repeated twice. The order of the twelve blocks varied

across participants. The participants were instructed to signal as quickly as possible the occurrence of deviant emotional face (ANGER, FEAR, DISGUST or HAPPINESS) by pressing a mouse button with their right index finger. The entire experiment took approximately 50 minutes per participant.

### 2.2. Recording

During the ERPs recording, participants sat in a chair in a dark room with their head placed 1 m from the screen and restrained in a chin rest. The electroencephalogram (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, but were re-referenced by using a "common average" (Bertrand, Perrin & Pernier, 1985). The EEG was amplified by battery-operated A.N.T.® amplifiers with a gain of 30,000 and a band-pass of 0.01–100 Hz. The impedance of all electrodes was kept below 10 kΩ. The EEG was continuously recorded (sampling rate 500 Hz, Eeprobe software, A.N.T.) and the vertical electrooculogram (VEOG) was recorded in a bipolar manner from electrodes placed on the supraorbital and infraorbital ridges of the left eye. Trials contaminated by EOG artifacts were eliminated off-line by computing an average artifact response based on a percentage of the maximum eye movement potential. The EOG response was therefore subtracted from the EEG channels on a sweep-by-sweep, point-by-point basis in order to obtain ocular artifact-free data. A baseline correction was computed using a 200 ms interval. Epochs beginning 100 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. Data were filtered with a 30 Hz low-pass filter.

### 2.3. Data analysis

Two parameters were coded for every stimulus: (1) the type of stimulus (rare Happy, rare Fear, rare Disgust, rare Anger and, in order to have the same number of averaged frequent stimuli, only the frequent stimuli preceding the deviant ones); and (2) the type of response (keypress for deviant stimuli, no keypress for frequent ones). This coding allowed for the computation of different averages of ERP target stimuli. The averages were made for each participant individually. Peaks of interest are described subsequently.

Statistical analyses were computed using SPSS 14.0. We conducted repeated-measures ANOVA (more details will be provided in 3.3.1, 3.3.2 and 3.3.3 points). Greenhouse-Geiser epsilon correction was used to compensate for violation of sphericity when appropriate. Simple effects analyses of factors were explored throughout, using Bonferroni post-hoc tests and paired Student *t*-tests when appropriate. The sources of significant interactions were systematically examined through simple effects. The alpha level of significance was set at 0.05 throughout.

## 3. Results

### 3.1. Psychometrical features

Group did not differ in term of age ($t(21)=.291$, N.S.) or depression level ($t(21)=1.673$, N.S.). The high social anxiety group scored higher than the low social anxiety group on measurements of social anxiety, as for FNE ($t(21)=6.620$, $p<.001$) as for the Liebowitz Scale ($t(21)=8.277$, $p<.001$) but not on state ($t(21)=.952$, N.S.) or trait anxiety ($t(21)=1.811$, N.S.). In conclusion, our groups only differed on the base of the presence or absence of social anxiety, and did not present high trait-anxiety or depressive features.

### 3.2. Behavioral data

Behavioral data are presented in Figure 18. The performance was at 97% correct, analyses were thus conducted only on correct response latencies. Analyses disclosed a main effect of trial type ($F(3,63) = 78.997$, $p < .001$): Angry and fearful faces were slower detected as compared to disgust and happy faces (all $p$-value $p<.001$), and anger gave rise to longer response latencies, while disgusted faces were detected faster than happy ones ($p=.029$). Group did not significantly influence response latencies ($F(3,63) = .448$, N.S.)

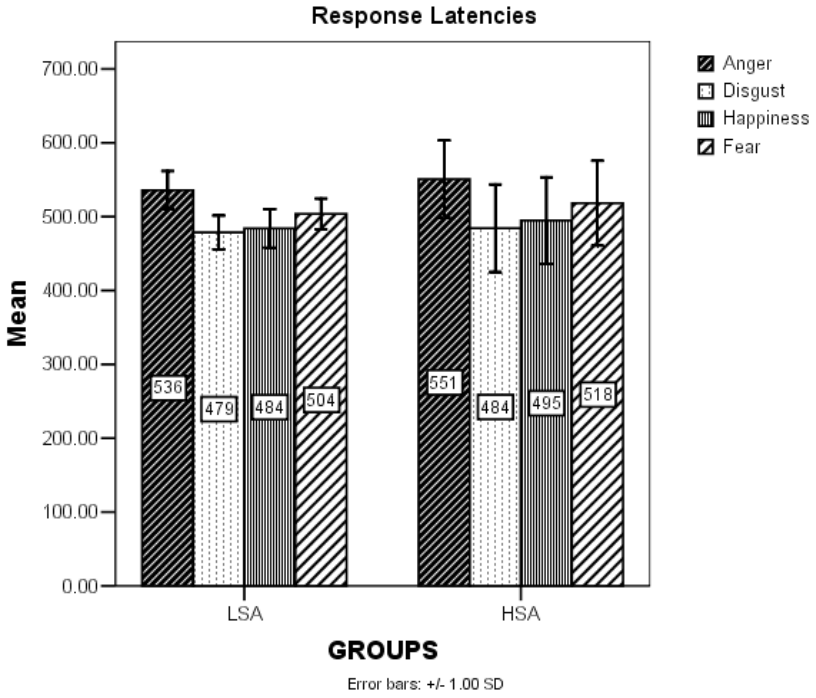


**Figure 18 : Behavioral performances.**

### 3.3. ERP results

Initial visual inspection of the non-subtracted ERP waves suggested different consecutive phases of attentional effects (see Figure 19). There were (a) an occipital P100 enhancement (100-200 ms), (b) a frontal N100 enhancement (100-200ms), (c) parieto-temporal N170 effect (150-250ms), a fronto-central N300 component (250-400ms), and (d) a parieto-occipital P300 effect (400-550ms). Tables 5, 6, 7, 8 and 9 present latencies and amplitudes values for each of these components for LSA and HSA groups, averaged on interest electrodes.

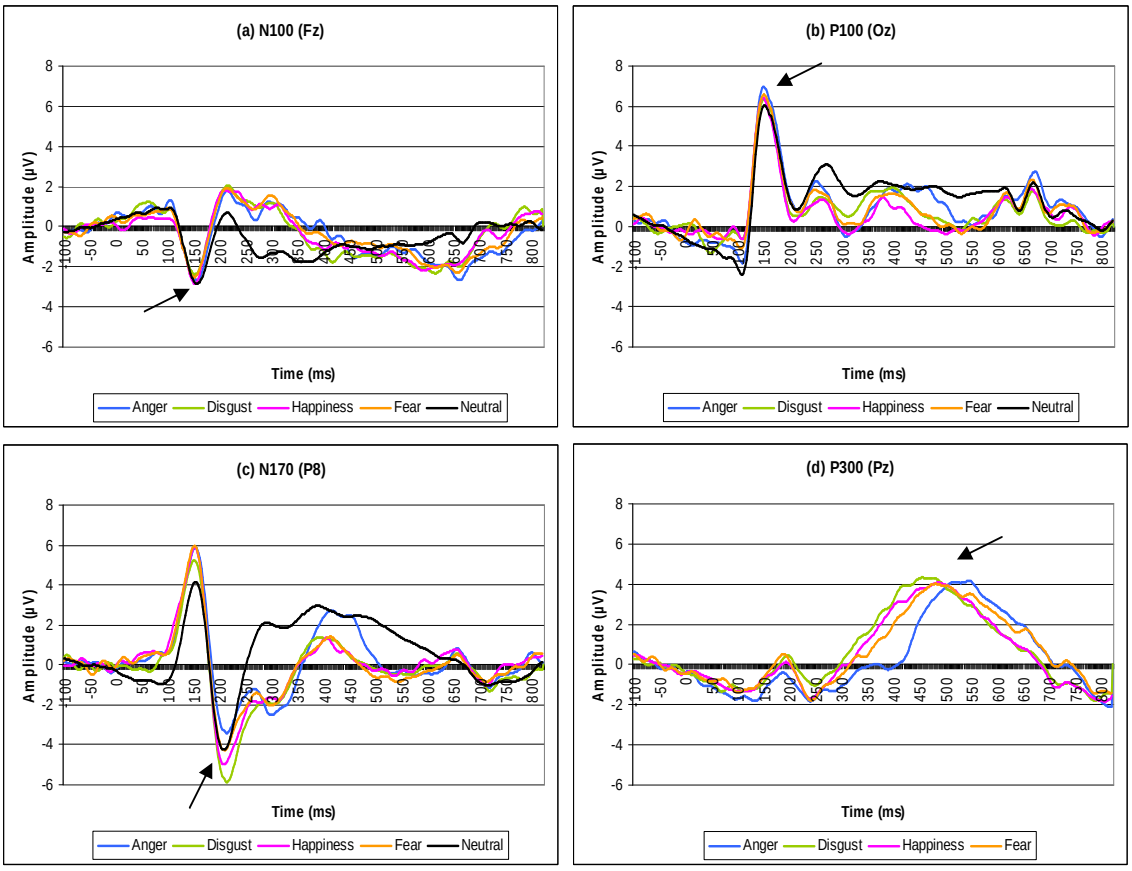


**Figure 19 : Trial Type effects on N100, P100, N170 and P300 waves, represented on midline electrodes (except for N170 represented on P8): N100 was delayed for neutral frequent trials, P100 was enhanced for rare emotional trials, N170 was amplified for Happiness and Disgust and reduced for Anger, and P300 was delayed for Anger.**

### 3.3.1. P100 and N100 components

The P100 and N100 attention waves were identified as the maximum and the minimum points recorded in a temporal window going from 100 to 200ms after the stimulus onset, from the channels Fz, F3, and F4 for the N100 (see Table 5) and Oz, O1, O2 for the P100 (see Table 6). These measures were submitted to two mixed design MANOVAs on latency and amplitude, with

group (HSA - LSA) as between-subjects factor, and Trial Type (Frequent, Anger, Happy, Fear, and Disgusted), and Laterality (left, midline, right) as within-subjects factors. Significant effects were decomposed subsequently[13].

Trial Type significantly affected the N100 attentional wave ($F(4,84) = 4.592$, $p = 0.016$) : N100 was delayed for neutral faces as compared to fearful ($p = .045$), happy ($p < .001$) or disgusted faces ($p = .02$).

Trial Type also acted on P100 amplitudes ($F(4,84) = 5.510$, $p = 0.001$), indicating an enhanced P100 wave in response to emotional faces as compared to neutral ones (disgust : $p = .015$ ; anger : $p < .001$ ; fear : $p = .008$ ; happiness : $p = .039$), but without significant difference between these emotions. In consequence, the presence of an emotion on perceived faces influenced the production of early perceptual waves (except for angry faces which did not modify N100 latency), but there was no influence of emotion type. As emotional faces constituted rare stimuli to detect, this effect could reflect the orientation of attentional resources towards relevant stimulation, through a top-down modulation of visual processes (Mangun & Hillyard, 1996). Trial type effects on visual attentional waves are represented in Figure 20, boxes a and b.

[13] As the ratio of male and female participants differed between HSA and LSA groups and that gender has been associated to modulation of emotional processing (Campanella et al., 2004), we conducted a first analysis taking the gender factor into consideration, additionally to trial type and social anxiety level. However, this variable did not significantly act on the results. In consequence, we removed it in order to simplify the presentation of result section.

**Table 5: Mean latencies (ms) and amplitudes (µV) (standard deviation) for N100, averaged on F3, F4 and Fz electrodes, for each groups and mean values for both groups.**

| | | A | D | H | F | FQT |
|---|---|---|---|---|---|---|
| **LSA** | **Lat** | 151 (11,27) | 149 (12,05) | 148 (6,57) | 152 (10,15) | 154 (9,69) |
| | **Ampl** | -2,68 (0,68) | -2,19 (0,98) | -2,14 (1,29) | -2,19 (1,25) | -2,56 (0,84) |
| **HAS** | **Lat** | 153 (10,87) | 148 (12,49) | 147 (9,88) | 148 (10,38) | 153 (9,06) |
| | **Ampl** | -3,38 (1,41) | -3,59 (1,75) | -4,02 (1,90) | -3,62 (2,24) | -3,56 (1,66) |
| **Mean** | **Lat** | 152 (10,86) | 149 (12,01) | 148 (8,31) | 150 (10,22) | 154 (9,18) |
| | **Ampl** | -3,04 (1,15) | -2,92 (1,57) | -3,12 (1,87) | -2,94 (1,94) | -3,08 (1,40) |

**Table 6: Mean latencies (ms) and amplitudes (µV) (standard deviation) for P100, averaged on O1, O2 and Oz electrodes, for each groups and mean values for both groups.**

| | | A | D | H | F | FQT |
|---|---|---|---|---|---|---|
| **LSA** | **Lat** | 147 (9,09) | 149 (9,21) | 148 (5,69) | 150 (9,33) | 149 (8,54) |
| | **Ampl** | 7,12 (2,26) | 5,89 (2,08) | 5,66 (2,06) | 6,01 (1,73) | 5,47 (2,19) |
| **HAS** | **Lat** | 151 (10,00) | 148 (8,22) | 150 (10,61) | 148 (7,55) | 152 (8,97) |
| | **Ampl** | 9,03 (2,87) | 8,80 (3,04) | 8,82 (3,24) | 8,72 (3,02) | 7,81 (2,52) |
| **Mean** | **Lat** | 149 (9,62) | 149 (8,51) | 149 (8,47) | 149 (8,28) | 151 (8,69) |
| | **Ampl** | 8,12 (2,72) | 7,40 (2,96) | 7,31 (3,13) | 7,43 (2,80) | 6,69 (2,61) |

Lateralisation affected N100 ($F(2,42) = 4.592$, $p = 0.016$) and P100 ($F(2,42) = 7.252$, $p < .001$) amplitudes : the N100 component was larger in the midline electrode than on the left side ($p = .011$), while in contrast, a decreased P100 at midline electrode was observed compared to the right side ($p < .001$).

Group significantly modified N100 ($F(1,21) = 5.507$, $p = 0.029$) and P100 ($F(1,21) = 6.807$, $p = 0.016$) amplitudes : HAS produced higher N100/P100 complex (-3.637 and 8.636µV) than LSA (-2.352 and 6.03µV). The absence of interaction between group and Trial Type meant that HSA evoked enhanced P100/N100 both for neutral faces both for emotional ones. Figure 20 represents this enhancement of that visual complex.

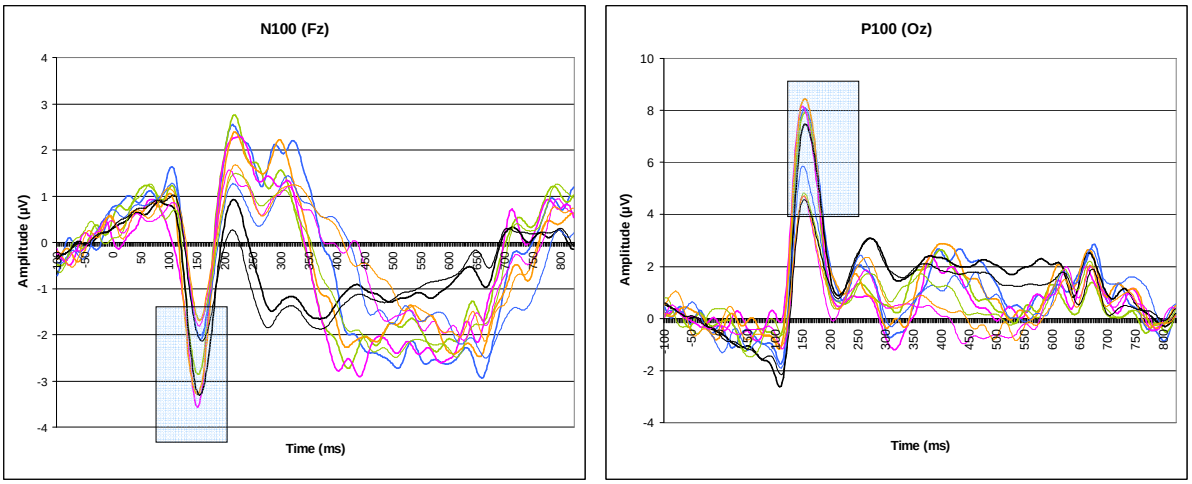


**Figure 20 : Enhanced N100/P100 complex in HSA as compared to LSA group for the different trials types (HSA : bold lines ; LSA : thin lines ; Anger : blue ; Disgust : green ; Happiness : pink ; Fear : orange ; Neutral : black lines).**

### 3.3.2. N170 effects

N170 was identified as the minimum value recorded from the channels P7 and P8 in a temporal window going from 150 to 250ms after the stimulus onset (see Table 7). These measures were submitted to two repeated-measures MANOVAs on latency and amplitude, with group (HSA and LSA) as between factor, and Trial Type (Frequent, Anger, Happy, Fear, and Disgusted) and Laterality (left or right) as within-subjects factors.

**Table 7 : Mean latencies (ms) and amplitudes (µV) (standard deviation) for N170 component, averaged on P7 and P8, for each groups and mean values for both groups.**

| | | A | D | H | F | FQT |
|---|---|---|---|---|---|---|
| **LSA** | **Lat** | 208 (12,55) | 212 (17,86) | 205 (14,47) | 210 (14,06) | 203 (11,23) |
| | **Ampl** | -3,72 (2,76) | -5,80 (3,54) | -5,55 (3,25) | -4,57 (2,85) | -3,87 (2,50) |
| **HAS** | **Lat** | 207 (11,61) | 203 (10,45) | 205 (15,63) | 208 (15,19) | 203 (11,19) |
| | **Ampl** | -4,25 (3,19) | -6,04 (3,79) | -6,01 (2,85) | -5,04 (3,57) | -4,75 (2,13) |
| **Mean** | **Lat** | 208 (11,82) | 207 (14,91) | 205 (14,75) | 209 (14,34) | 203 (10,95) |
| | **Ampl** | -4,00 (2,93) | -5,92 (3,59) | -5,79 (2,99) | -4,81 (3,18) | -4,33 (2,31) |

Statistical analysis did not reveal any significant effect of latency on this wave.

Amplitude was influenced by Trial Type ($F(4,80) = 17.725$, $p < .001$) in such a way that N170 was larger for disgusted faces, as compared to angry, neutral and fearful faces (all $p$-values <.001, no difference as compared to happiness). Happy faces also evoked enhanced N170 compared to anger, neutral (both $p$-values <.001) and fear ($p$=.005). At the opposite, anger elicited reduced waves (comparison to fear: $p$<.001), followed by neutrality. That effect is represented on Figure 19, box c.

Lately, a significant interaction between Trial Type and Laterality ($F(4,80) = 3.723$, $p$=.015) indicated enhanced amplitude on the right hemisphere for all type of trials except for anger.

Group did not significantly affect N170 parameters (Latency: $F(1,20) = .820$, N.S. ; Amplitude ($F(1,20) = .565$, N.S.).

### 3.3.3. N300 effects

N300 was identified as the minimum value recorded in a temporal window going to 250 to 400ms after the stimulus onset, at the frontal (F3-F4-Fz) and central (C3-Cz-C4) electrodes (see Table 8).

These measures were submitted to two mixed design MANOVAs on latency and amplitude, with group (HSA and LSA) as between factor, Trial Type (Frequent, Anger, Happy, Fear, and Disgusted), Site (Frontal vs Central Electrodes) and Laterality (left or right) as within-subjects factors.

**Table 8 : Mean latencies (ms) and amplitudes (µV) (standard deviation) for N300 component, averaged on interest electrodes, for each groups and mean values for both groups.**

| | | A | D | H | F | FQT |
|---|---|---|---|---|---|---|
| **LSA** | **Lat** | 327 (23,95) | 330 (28,80) | 307 (18,80) | 315 (21,01) | 303 (35,26) |
| | **Ampl** | -1,93 (0,74) | -2,07 (0,94) | -1,89 (0,99) | -1,61 (0,71) | -2,03 (0,65) |
| **HAS** | **Lat** | 313 (33,03) | 320 (31,52) | 331 (32,77) | 329 (38,52) | 324 (29,90) |
| | **Ampl** | -1,89 (1,32) | -2,43 (1,44) | -2,50 (1,41) | -2,26 (1,44) | -1,95 (0,74) |
| **Mean** | **Lat** | 320 (29,37) | 325 (30,03) | 320 (28,98) | 322 (31,55) | 314 (33,53) |
| | **Ampl** | -1,91 (1,06) | -2,26 (1,22) | -2,21 (1,24) | -1,95 (1,17) | -1,99 (0,69) |

The main effects of Trial Type and Group did not reach significance, but a significant interaction between Group and Trial Type on N300 latencies was observed ($F(4,84) = 3.769$, $p=.013$). Figure 21 illustrated that effect: LSA produced earlier N300 for neutral and happy faces, but that wave was delayed for negative emotions and particularly for disgust. At the opposite, HSA produced earlier emotional wave for angry faces, followed by disgusted ones. As a consequence, the pattern of emotional appraisal was completely different

in these groups, HSA participants favored appraisal of negative emotional faces whereas that evaluation took more time in low social anxious participants.

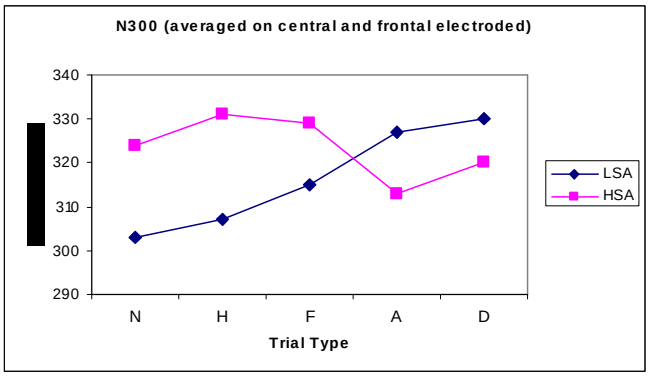


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**Figure 21 : N300 latencies as a function of trial type and groups.**

A second interaction between Site of Recording and Trial Type influence N300 latencies ($F(4,84) = 5.393$, $p=.002$) and amplitudes ($F(4,84) = 14.650$, $p<.001$). Indeed, Anger elicited earlier latencies in frontal areas but higher amplitudes on central sites. Comparable results were observed for Fear, despite a less important latency difference. Amplitudes were also enhanced on central electrodes for disgust and happiness, coupled with earlier latencies. At the opposite, Neutrality evoked higher N300 on frontal areas.

### 3.3.4. P300 effects

Figure 19d represents the P300 observed in both groups and identified within a temporal window going from 400 to 550ms at the parietal electrodes P3, Pz and P4 for emotional faces to detect (see Table 9).

**Table 9 : Mean latencies (ms) and amplitudes (µV) (standard deviation) for P300 component, averaged on P3, Pz and P4 electrodes, for each groups and mean values for both groups.**

| | | A | D | H | F |
|---|---|---|---|---|---|
| **LSA** | **Lat** | 498 (24,94) | 436 (48,19) | 462 (49,92) | 477 (37,93) |
| | **Ampl** | 3,81 (1,22) | 4,41 (1,44) | 4,17 (1,79) | 3,73 (1,37) |
| **HAS** | **Lat** | 498 (41,98) | 445 (43,20) | 457 (54,66) | 463 (39,87) |
| | **Ampl** | 4,78 (1,59) | 4,98 (1,58) | 4,83 (1,43) | 4,94 (1,42) |
| **Mean** | **Lat** | 498 (34,11) | 441 (44,82) | 459 (51,31) | 470 (38,72) |
| | **Ampl** | 4,31 (1,48) | 4,71 (1,51) | 4,51 (1,61) | 4,36 (1,50) |

Two mixed design MANOVAs were computed on latency and amplitude, with group (HSA and LSA) as between-subjects factor, and Trial Type (Anger, Happiness, Disgust and Fear), and Laterality (left, midline, right) as within-subjects factors. Analysis disclosed a main effect of Trial Type in latency ($F(6,63) = 15.315$, $p < .001$) : angry faces elicited significantly delayed P3b as compared to disgust, happy or fearful faces (all $p$-values $\leq .001$). Fear also evoked a later P3b, compared to disgust ($p = .003$) that evoked earlier decisional wave similar to happiness. In consequence, the two emotions described to be the most threatening evoked a delay in the production of decisional and closure processes, as represented by Figure 19, box d.

Finally, P3b amplitude was only affected by Laterality ($F(2,42) = 10.580$, $p < .001$): P3b was enhanced on the central side (5.132µV) as compared to left (4.077µV, $p < .001$) or right side (4.155µV, $p < .001$).

Group did not affect P300 latency or amplitude, and did not interact with Trial Type, Site, or Laterality.

### 3.4. Correlational analyses

Pearson's correlations were performed on component's latencies and amplitudes, responses latencies, and scores to psychometrical tests, across the entire sample. The results, shown in Table 10, clearly confirm that scores on social anxiety scales, FNE and LSAS, are positively associated with amplitudes of N100/P100 complex, without link with trait or state anxiety scales[14]. On the other hand, N300 and P300 latencies and amplitudes are associated with parameters of N170, indicating that emotional appraisal and closure mechanisms depend of evaluation of structural features of face stimuli.

Lastly, a regression model using a backward procedure (removing successively the less predictive factors) demonstrated that the best predictors of response latencies are N300 amplitudes and P300 latencies ($F(2,20)=9.790$, $p=.001$), which explain together almost 50% of their variability ($r^2=.495$).

[14] Correlations were also calculated by including the trial type factor, in order to control an emotional specificity. However, significant correlations were present for all types of trials, excluding the hypothesis of a specificity for some emotions.

**Table 10: Pearson's correlations and level of significance (*.05 ; ** .01; ***.001) between ERP components' latencies and amplitudes (italic), response latencies and psychometrical evaluation.**

| | | N100 | | P100 | | N170 | | N300 | | P300 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A | L | A | L | A | L | A | L | A | L |
| N100 | A | | 0.057 | -0.814 *** | -0.024 | -0.020 | 0.256 | 0.295 | 0.111 | 0.029 | 0.172 |
| | L | 0.057 | | -0.064 | 0.806 *** | 0.469 | 0.699 *** | 0.449 * | -0.180 | -0.271 | 0.186 |
| P100 | A | -0.814 *** | -0.064 | | 0.157 | 0.028 | -0.298 | -0.301 | 0.006 | 0.211 | -0.199 |
| | L | -0.024 | 0.806 *** | 0.157 | | 0.469* | 0.665 *** | 0.474 * | -0.324 | -0.102 | 0.238 |
| N170 | A | -0.020 | 0.469* | 0.028 | 0.469 * | | 0.317 | 0.499 * | -0.481 | -0.549 | 0.621 |
| | L | 0.256 | 0.699 | -0.298 | 0.665 *** | 0.317 | | 0.658 *** | -0.316 | -0.342 | 0.222 |
| N300 | A | 0.295 | 0.449 * | -0.301 | 0.474 | 0.499 | 0.658 *** | | -0.269 | -0.505 | 0.444 * |
| | L | 0.111 | -0.180 | 0.006 | -0.324 | -0.481 * | -0.316 | -0.269 | | 0.252 | -0.366 |
| P300 | A | 0.029 | -0.271 | 0.211 | -0.102 | -0.549 ** | -0.342 | -0.505 ** | 0.252 | | -0.446 * |
| | L | 0.172 | 0.186 | -0.199 | 0.238 | 0.621 *** | 0.222 | 0.444 * | -0.366 | -0.446 * | |
| TR | | -0.318 | -0.112 | 0.329 | -0.078 | 0.040 | -0.410 * | -0.379 | 0.073 | 0.055 | 0.363 |
| LSAS | | -0.403 * | -0.105 | 0.482 * | -0.003 | -0.248 | -0.228 | -0.123 | 0.319 | 0.237 | -0.186 |
| FNE | | -0.412 * | 0.263 | 0.465 * | 0.343 | -0.085 | 0.115 | -0.040 | 0.077 | -0.012 | -0.148 |
| STAI-A | | 0.230 | 0.065 | 0.030 | 0.079 | -0.061 | -0.059 | 0.148 | 0.305 | -0.059 | 0.137 |
| STAI-B | | 0.279 | -0.121 | -0.383 | -0.061 | 0.077 | 0.023 | -0.030 | -0.387 | -0.151 | -0.095 |
| BECK | | 0.166 | 0.189 | -0.049 | 0.349 | 0.115 | 0.163 | 0.007 | -0.142 | 0.096 | -0.042 |

## 4. Discussion

The main purpose of this study was to evaluate the electrophysiological correlates produced during the detection of rare emotional stimuli in individuals reporting low or high social anxiety. Numerous behavioral studies have reported biases in emotional processing of socially anxious individuals (Fox, 2002; Fox et al., 2000; Garner et al., 2006; Mogg & Bradley, 2002; Mogg et al., 2004), but cognitive processes responsible of these biases remain largely unknown.

Due to their precise temporal resolution, ERP might help to define the origins of emotional biases in cognitive processing, and to link neurophysiological processes and behavioral observations. To this end, participants were recruited on bases of their scores on the Liebowitz Social Anxiety Scale (Liebowitz, 1987). This inventory measures both social anxiety and avoidance of social situations, the two central features of social phobia, which makes it particularly suited for the study of social phobia, even in sub-clinical samples (see for instance Garner et al., In Press). Participants were presented a modified version of the oddball task of Rossignol et al. (2005) and had to detect rare stimuli presenting expressions of fear and happiness but also anger and disgust, as far as these two emotions were described as particularly relevant in the social anxiety (Amir et al., 2005; Rossignol et al., 2007).

### 4.1. Role of social anxiety

Social anxiety was associated with modulation of the early perceptual stages of face processing, indexed by an enhanced N100/P100 complex. The direct link between this enhancement and social anxiety was confirmed by significant correlations between amplitudes of this perceptual complex and scores on social anxiety scales, replicating previous findings (Kolassa et al., 2007; Kolassa & Miltner, 2006; Rossignol, Philippot, Bissot & Campanella, Submitted-c). These results are in line with Mogg and Bradley' hypothesis (2002) that vigilance for faces would be primarily a function of social anxiety and social avoidance, rather than trait-anxiety, which was not associated with comparable disturbances of early perceptive complex in studies using comparable oddball paradigms (Rossignol et al., 2008; Rossignol et al., 2005).

Importantly, the perceptual enhancement was not limited to rare emotional faces, but was also observable for frequent neutral faces, as previously demonstrated (Kolassa et al., 2007). Several hypotheses may explain this result. Firstly, individuals with social phobia might show a general hypervigilance in link with the performance situation evoked by the achievement of an experiment (Kolassa et al., 2007). Indeed, the lack of emotional specificity may traduce an hypervigilance in the visual cortex, which enhanced attention (P100 component) and perceptual processing of incoming events. Conversely, a specific hypervigilance for faces has been attributed to social anxiety (Mogg & Bradley, 2002) and socially anxious participants may be vigilant to face, regardless of their emotional expression. As a consequence, a second hypothesis may be a hypervigilance, but

specifically for faces objects. Nevertheless, the absence of non-facial stimuli in the task does not allow to decide between these two hypotheses. Lastly, Yoon and Zinbarg (2008) have proposed that neutral faces are not perceived as neutral in social anxiety, and the report of differential amygdala activation for neutral faces in social anxiety sustained this hypothesis (Cooney et al., 2006). Therefore, the enhancement of N100/P100 in social anxious participants could reflect a global hypervigilance, an increased vigilance to faces, and/or an over-attribution of emotional content to neutral faces.

Conversely, other studies have observed earlier N100/P100 complex without emotional specificity (Bar-Haim et al., 2005) and higher P100 for fearful faces in high trait-anxiety participants (Holmes et al., 2008). Latencies have been associated to the speed of processing, and not to its intensity (Cardenas et al., 2005), the earlier perceptual response in trait anxiety might thereby index the over-reactivity of trait-anxious individuals, and the enhanced P100 for fearful face exclusively the specificity of threat processing in trait-anxiety. Moreover, in both case, authors did not report the level of social anxiety[15], which could have been increased in high trait anxious participants given the high correlation between these measures (Velardi et al., 2006). As a consequence, these finding strengthened the importance of a precise definition of anxiety type.

[15] Bar-Haim et al. controlled the social desirability reported by their participants, but this measure does not recover the same features than social anxiety and social avoidance evaluated in LSAS.

The N170 was not modulated by social anxiety. In past literature, enhancement of the N170 wave in social anxiety has been reported during a task requiring conscious identification of angry expression (Kolassa & Miltner, 2006). Our study did not require conscious emotional appraisal or face processing, and it is possible that such emotional perception counterbalances the influence of social anxiety on N170 wave.

The absence of demand of an explicit evaluation of the EFE may also be responsible for the absence of modulation of P300 by social anxiety. The lack of social anxiety influence on P300 has already been reported (Kolassa et al., 2007) and the preservation of decisional-related stages may be a specific property of emotional processing is social anxiety. However, a recent study reproducing the present paradigm in a group of subjects suffering from social anxiety demonstrated a correlation between the score of social anxiety and the amplitude of P300 in response to angry EFE (Sewell et al., 2008), while our analyses only reported correlations with parameters of early perceptual waves. However, Sewell et al. (2008) did not report the level of trait anxiety of their socially anxious participants. Hence, the presence of an unmeasured trait-anxiety might be responsible for the enhancement of the P300 wave in Sewell et al.' study, as a latent social anxiety could have modulated the results obtained by Bar-Haim et al. or Holmes et al. on early perceptive ERP components. Consequently, a precise evaluation of type of anxiety reported by participants seems required in further studies in order to confirm the differential influence of social anxiety on early perceptual mechanisms and the specific influence of trait-anxiety on later closure-related processes.

Nonetheless, the emotional appraisal is affected by social anxiety, as demonstrated by N300 modulations. Indeed, non-anxious participants produced quicker evaluation of neutral and happy faces, while negative facial expressions gave rise to a delayed N300. However, in social anxiety, the emotion evoking the faster emotional appraisal is anger, followed by disgust. Emotional appraisal has already been shown to be affected by trait anxiety (Rossignol et al., 2005), and previous data have suggested a very particular status of anger and disgust in social anxiety (Amir et al., 2005; Montagne et al., 2006; Phillips et al., 1998b; Rossignol et al., 2007). For instance, in an oddball paradigm involving categorical perception with morphed faces varying from disgust to anger, socially anxious subjects needed less attentional resources, indexed by a decreased N2b, to detect deviant faces displaying more intense expression of anger (Rossignol et al., 2007). On the other hand, social anxious participants produced an enhanced N2b, interpreted as the sign of the allocation of a larger amount of attentional resources, to detect angry faces appearing amongst disgusted faces, as if they have difficulties to disengage from frequent faces displaying disgust to detect angry faces. These observations are congruent with the notion of an easier detection of threatening stimuli in anxiety and confirmed the role of disgust in the capture of attention in social anxiety, as already suggested by several authors (Amir et al., 2005; Simonian, Beidel, Turner, Berkes & Long, 2001). The current results of an earlier N300 in social anxious participants for anger and disgust bring a new confirmation of these data.

Despite these modulations of ERP components, low and high socially anxious participants did not differ on the bases of behavioral results. Previous ERP studies on emotional processes in anxiety have shown that modulations of earlier ERP did not systematically result in behavioral differences (see for instance Holmes et al., 2008; Kolassa & Miltner, 2006), whilst modifications of later components as P300 are more reliably associated with behavioral changes (Rossignol et al., 2008; Rossignol et al., 2005). At least two hypotheses might be advanced to explain the lack of effect on closure processes indexed by P300 component on behavioral measures. Firstly, socially anxious participants recruited in that study did not report state or trait anxiety. If we consider that trait anxiety is associated with the hypervigilance leading to faster behavioral responses but that social anxiety only implies fear of social evaluation, we might explain that absence of behavioral effect by the specific characteristics of our participants. Other ERP studies conducted with socially anxious participants did not observe behavioral modification (Kolassa & Miltner, 2006; Moser et al., 2008), while trait anxiety alone (Rossignol et al., 2008; Rossignol et al., 2005) or cumulated with social anxiety (Rossignol et al., 2007) led to observations of accelerated responses. Hence, the absence of trait anxiety may explain the lack of change in behavioral performance.

A second hypothesis to explain the absence of behavioral facilitation by social anxiety relates to the task used in this study. The detection of rare amongst frequent stimuli is a very simple task, implying vigilance abilities impaired in deep psychopathological states such as schizophrenia (Campanella,

Montedoro, Streel, Verbanck & Rosier, 2006) or chronic alcoholism (Maurage et al., 2007), but probably not in individuals experiencing social anxiety at a sub-clinical level. Yet, if the hypervigilance associated to sub-clinical trait anxiety is sufficient to generate faster reaction to deviance, it is not surprising that sub-clinical social anxiety does not. As a result, this kind of oddball paradigm might be too effortless to evidence subtle change in behavioral response linked to social anxiety.

### 4.2. Emotional effects

A second point to discuss concerns the emotional effects observed in this study. Indeed, behavioral results yielded a surprising observation: the EFE of anger and fear, far from being more quickly detected, are the ones that elicited the longest response times while facial expressions of disgust were the most quickly detected. These results deviate from those reporting usually a faster detection of threat signals (Vuilleumier, 2002). However, while most of studies reporting threat advantage contrast a positive and a negative stimulus (e.g. happy and fearful faces, or happy and angry faces, sometimes contrasted with neutral faces - Mogg et al., 2004; Pourtois et al., 2004; Rossignol et al., 2005), the present study presented four types of emotional stimuli, among whom three are negatively valenced.

Moreover, when two types of deviant stimuli are confronted, one negative and the other one positive, the subject can grant preferentially his attention to the most negative stimulus and treat it more quickly. However, when various types of negative stimuli are in competition, one might speculate

an implicit categorization of these, delaying following processing. A similar observation of faster response to disgust and happiness in visual search tasks implying several EFE types has already been reported (Calvo & Nummenmaa, 2008). These authors have suggested that the high uniformity of happy facial expression makes it easy to recognize, while anger is characterized by a greater featural variability. In the present study, the more salient features of happiness and disgust may have facilitated their detection, when a competition between fear and anger might elicit a longer categorization process. According to this featural explanation, the delayed detection of the most threatening EFE might be attributable to the division of the attentional resources required by the detection of several types of negative deviant stimuli. This rationale is supported by the modification of the distribution of N300 for anger and fear facial expressions, as if the emotional appraisal appeared as modulated by the salience of these emotions (Schutter et al., 2004) and evoked a more detailed but also slower process of response preparation, indexed by delayed P300 for anger and fear. That hypothesis is also sustained by the correlations between N300 amplitudes and P300 parameters.

Emotional appraisal and closure mechanisms were related to facial structural encoding. Indeed, the emotional modulation of the processing of deviant emotional stimuli began at 150 ms SOA, since N170 was also specifically modulated by the emotional load, supporting previous observations (Batty & Taylor, 2003). This wave, reflecting the encoding of the structural characteristics of facial stimuli, was increased for disgusted and happy facial expressions, but decreased for anger. In the literature, decreased

amplitudes are often interpreted in terms of reduction or deficit of the subjacent process (see for instance Campanella et al., 2006). Therefore, our observation could reflect a shallower encoding of angry faces' features, when these stimuli appear alternately with others rare negative stimuli to detect. To sum up, reduced emotional appraisal, delayed response-preparation, and finally slower behavioural responses might have resulted from that diminished facial processing of angry EFE.

Previous stages of processing did not reflect major modification for these emotions: P100 was enhanced and N100 appeared earlier in response to emotional stimuli. However, the absence of non-emotional deviant stimuli does not allow to test the hypothesis of an emotional specificity. As emotional faces constituted rare stimuli to detect, the enhancement of visual processes for the task-relevant stimuli might more generally index a visual preparation for the detection of target-stimuli, through the influence of top–down processes.

To summarize our results, rare emotional stimuli elicited enhanced early visual responses. However, this initial global enhancement was followed by differential appraisal of emotional faces: enhanced N170 for disgust and happiness, and delayed N300 for negative emotions and particularly for fear and anger. These two last emotions elicited delayed P300 component and later response latencies. In conclusion, we may postulate that emotional processing is indexed as early as 100ms after stimulus onset, but that the specific influence of facial expressions is apparent from 150-200ms and until

closure stages. These results support the notion of an early influence of stimuli-valence, followed by a later influence of stimuli-arousal (Olofsson et al., 2008).

### 4.3. General conclusion

This study showed that social anxiety led to early attentional modification without behavioral modifications. More precisely, we observed an early attention to faces, followed by a faster appraisal of negative emotional stimuli (anger and disgust), but without modulation of late, premotor stages of response preparation. Overall, these results have important implications for current definition of anxiety, because that pattern contrasts with the motor acceleration observed in trait anxiety (Rossignol et al., 2008; Rossignol et al., 2005), within a model of elevated arousal (Bishop, 2007). In the current study, we evidence globally enhanced N100/P100 in social anxious participants, as if the status of a face was more important that the displayed emotion. However, a limitation of that study is the absence of non-facial rare stimuli to detect. So, we cannot assert that this enhancement is specific to face, and not generalized to any kind of visual objects. A response would have been to integrate inverted faces to control the specificity of visual response to faces, as carried out by Sewell and collaborators (2008). Conversely, these authors did not investigate early visual processes, which are of particular interest when perceptual modulations are expected (Campanella et al., 2006). In consequence, further studies should investigate the specificity of face processing in social anxiety, as well as the modulation of behavioral performances in clinical groups or in more complex tasks.

## Introduction à la seconde question de recherche

Notre première question de recherche visait, à une époque où la littérature ne rapportait aucune donnée relative aux corrélats électrophysiologiques du traitement des visages dans l'anxiété, à mettre en évidence les étapes de traitement affectées par l'anxiété, et à comparer l'influence relative de l'anxiété trait et l'anxiété sociale.

Les résultats obtenus dans notre première étude, démontrant que le biais observable pour le traitement des EFE de peur n'est pas plus ample sur un plan comportemental chez les sujets présentant une anxiété trait élevée, semblaient aller à l'encontre des conclusions usuellement rapportées dans la littérature. En effet, les sujets anxieux ne présentaient pas de biais plus marqués dans la détection d'EFE de peur, et leur pattern de résultats indiquait une accélération du traitement en général, mais pas de modification spécifique en faveur du traitement de la menace.

Cependant, la démonstration d'altérations des étapes sous-jacentes du traitement cognitif, par la réduction du processus d'appraisal émotionnel indexé par la N300 (en particulier dans l'hémisphère droit) et la compensation via par un traitement décisionnel approfondi, confirme bien que le traitement des stimuli émotionnels est affecté par la présence d'anxiété, même sous-clinique et auto-rapportée. Les interprétations permises par l'utilisation de la méthode des potentiels évoqués doivent cependant être envisagées avec prudence. En effet, si une latence plus précoce indique sans conteste une accélération du processus sous-jacent, une diminution d'amplitude peut se lire comme reflétant une altération du processus, moins efficace et moins marqué,

mais aussi, alternativement, comme une facilitation de la mise en œuvre de ce processus. Si la réalisation d'une étape de traitement est plus simple pour un sujet, celui-ci y consacrera moins de ressources, et l'amplitude de l'onde résultante sera plus faible, sans que cela indexe une altération dans le sens négatif du terme.

Nous préférons donc tempérer les interprétations proposées dans l'article relatif à cette première étude, en postulant une accélération du processus décisionnel associé à une modulation du processus d'évaluation émotionnelle.

Les participants sélectionnés pour cette première étude rapportaient des niveaux élevés d'anxiété trait et état en l'absence de dépression. Par contre, leurs scores d'anxiété sociale n'avaient pas fait l'objet d'un contrôle particulier, notre critère de sélection excluant simplement les individus obtenant un score supérieur à 18 à l'échelle FNE (selon les critères mentionnés par Douilliez & Philippot, 2003). Etant donné que la littérature rapporte des phénomènes de biais émotionnels comparables sur le plan comportemental dans l'anxiété trait et l'anxiété sociale, nous nous sommes interrogé sur la similarité des corrélats neurophysiologiques du traitement des EFE dans ces deux désordres.

Notre seconde étude visait donc à étudier l'impact concret d'une classification des sujets comme souffrant ou pas d'anxiété sociale, mais en l'absence d'anxiété générale de type trait. L'emploi d'un paradigme comparable garantissait la possibilité de comparer les performances des sujets dans ces deux études, et nous avons désiré explorer un plus large panel d'émotions en ajoutant comme stimuli rares à détecter des expressions de

colère et de dégoût, dans la mesure où ces deux émotions ont également été décrites comme particulièrement pertinentes dans l'anxiété sociale.

Les résultats de cette seconde étude contrastent singulièrement avec ceux de l'étude précédente. En effet, si l'anxiété trait était associée à des modifications relativement tardives du traitement émotionnel, l'anxiété sociale s'associe à des modulations précoces, apparaissant entre 100 et 400ms après la survenue du stimulus. Plus précisément, après une étape perceptive accrue pour les visages neutres et émotionnels, l'évaluation de la charge émotionnelle des émotions de colère et de dégoût apparaissait comme accélérée chez les participants rapportant une anxiété sociale élevée. A l'opposé, les expressions de neutralité, de peur et de joie étaient évaluées plus tardivement que chez les sujets rapportant une anxiété sociale faible.

D'autre part, nous ne reproduisons pas l'effet d'accélération de la réponse observé dans l'anxiété trait, et l'étape de préparation motrice (indexée par l'onde P300) ne démontrait aucune influence de l'anxiété sociale.

Les résultats principaux de ces deux études peuvent donc être synthétisés de la manière suivante : l'anxiété trait n'affecte pas les processus de perception des stimuli faciaux, mais engendre une modulation de l'évaluation de la charge émotionnelle associée à une finalisation plus précoce du traitement cognitif et à une réponse comportementale plus rapide. Par contre, l'anxiété sociale module les étapes de perception des stimuli faciaux, et cette modulation attentionnelle précoce affecte les étapes d'évaluation émotionnelle. Toutefois, les étapes de clôture du traitement cognitif n'en sont pas affectées. En outre, les émotions de colère et de dégoût semblent susciter la modulation

la plus nette. Ainsi que nous l'avons vu dans la partie introductive de ce travail, ces deux émotions semblent porteuses d'un challenge tout particulier dans l'anxiété sociale (Amir et al., 2005; Montagne et al., 2006; Schofield et al., 2007).

Dans ce cadre, notre seconde question de recherche abordera plus précisément la question suivante : les émotions de colère et de dégoût présentent-elles un challenge particulier quant à leur traitement dans le cadre d'une anxiété sociale ?

Plus précisément, notre étude tente d'opposer le traitement effectué sur ces deux émotions lorsque celles-ci sont manipulées par une procédure de morphing permettant d'imprimer une gradation dans l'intensité des affects exprimés (Wilson & MacLeod, 2003). Dans la lignée des deux études précédentes, nous avons utilisé un paradigme oddball. La présentation d'un stimulus fréquent présentant une émotion donnée (dans notre étude, la colère ou le dégoût) et de stimuli rares présentant soit la même émotion à un niveau d'intensité plus élevé, soit l'autre émotion en balance permettra d'investiguer les processus de désengagement attentionnel en vue de la détection d'une cible. Ce procédé offrira donc d'investiguer quelle émotion, de la colère ou du dégoût, est la plus aisément détectée (impliquant le processus d'orientation de l'attention), et laquelle entraine les difficultés de désengagement les plus manifestes.

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# Chapitre 6 :

# Perception catégorielle de la colère et du dégoût dans l'anxiété sociale

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Rossignol, M., Anselme, C., Vermeulen, N., Philippot, P., and Campanella, S. (2007). Categorical perception of anger and disgust facial expression is affected by non-clinical social anxiety: an ERP study. Brain Research, 1132(1): p. 166-176.

## Abstract

Anxiety has been associated with a bias for interpreting threatening information. Faces expressing anger seem to be more easily detected by socially anxious individuals than by non-anxious individuals. Similarly, disgust on a face may also reflect a negative social judgment. We tested the hypothesis that individuals displaying non-clinical social anxiety would be as sensitive to disgust as to anger interpretation by comparing individuals scoring high or low on the fear of social evaluation scale (FNE, Watson and Friend, 1969). Event-related potentials (ERP) were recorded in response to repetitions of a particular facial expression (e.g. anger) and in response to two deviating (rare) stimuli obtained by a morphing procedure, where one depicted the same emotion as the frequent stimulus, while the other depicted a different facial expression (e.g. disgust). The classic effect of categorical perception was reproduced: at a behavioral level: people detected more easily rare faces depicting a different emotion than faces depicting the same emotion. ERP results suggest that deviant faces depicting a different emotion evoked an earlier attentional N2b/P3a wave complex, together with an earlier and enhanced P3b. More interestingly, participants with non-clinical social anxiety manifested a reduced N2b wave when they had to detect a change in intensity of anger presentation. However, these individuals did not show facilitation to disengage from disgust when they have to detect angry faces, which was displayed by control participants. Implications and suggestions for further research about the role played by anger and disgust in psychopathology are outlined.

## 1. Introduction

The categorical perception is a well-documented phenomenon in the field of human perception (Harnad, 1987). The process of categorisation consists in allocating to discrete categories different stimuli sharing some common properties. Through categorisation, linear physical changes are interpreted as having non-linear perceptual effects. For instance, the colour spectrum is defined by the variation of light frequencies, but we are able to perceive chunks of colours rather than a continuum of colour change.

Interestingly, authors have outlined that the discrimination of two stimuli perceived as stemming from two different categories is always easier than the distinction between two stimuli classified as belonging to the same category. This phenomenon of enhanced "between-category" differences compared to reduced "within-category" differences is called the categorical perception effect. To illustrate this effect, studies on colour perception have shown that individuals discriminate more easily two colours perceived as stemming from different categories (blue – green), than two colours belonging to the same category (blue - blue), even if the physical distances are identical between each pair (Harnad, 1987).

This phenomenon is not restricted to simple stimuli, and studies have shown that emotional faces are categorically perceived (Campanella et al., 2002a; Campanella et al., 2002b; Etcoff & Magee, 1992; Rossignol, Bruyer, Philippot & Campanella, Submitted-a; Young, Rowland, Calder, Etcoff, Seth & Perrett, 1997), even by 7 month-old infants (Kotsoni, de Haan & Johnson, 2001). The phenomenon of categorical perception of emotional expression is

often studied by using morphing procedure: artificial continua of interpolated (morphed) facial expressions are derived from two faces of the same individual portraying different prototypical emotions. In the study of Campanella et al. (2002a), pairs of faces separated by a constant physical distance of 30% were presented to participants who had to decide whether faces were identical or different. Three kinds of pairs were proposed: identical pairs (same faces), between pairs (two faces perceived as displaying two different emotions) and within pairs (two faces perceived as sharing the same emotion). Results showed that within pairs were harder to discriminate that between pairs, even if the physical distance within each pair was kept constant, highlighting that the performance is more influenced by category membership than by the objective physical distance (Campanella et al., 2002a; Campanella et al., 2002b).

Tanaka, Giles, Kremen and Simon (1998) gave an explanation to justify this categorical perception effect: different prototypes of the different emotional facial expressions would be stored in long-term memory, and would be activated when individuals see faces portraying emotional expressions. Thus, morphed faces of between-categorical pairs would activate two different representations, whereas the within-categorical pairs would be related to the same representation, and consequently would be more difficult to discriminate.

In an electrophysiological study, Campanella et al. (2002a) examined the neurophysiological correlates of this phenomenon, and recorded event-related potentials during an oddball task using morphed faces displaying fear and

sadness expressions. Participants were confronted with an identical stimulus repeated successively, and had to detect as quickly as possible rare stimuli depicting either the same emotion than the frequent ones (within-stimuli), either another emotion (between-pairs), the physical difference between frequent and rare faces remaining identical. Results showed a delayed N2b/P3a complex, known as representing an "attentional orienting complex" (Halgren & Marinkovic, 1995; Suwazono et al., 2000), in response to within deviant stimuli as compared to between-stimuli, and an enhanced P3a component for between stimuli, due to an increased attention directed towards the rare stimulus displaying a different emotion from the frequent one (Campanella et al., 2002a). This pattern of results suggests that categorical perception is driven by attentional processes.

Conversely, attention seems easily disrupted in psychopathological states, and current literature reports widespread evidences of attentional biases in emotional perception (see for example Philippot et al., 2003). Attentional biases have been especially established in several anxiety disorders as generalised anxiety disorder, obsessive compulsive disorder, specific phobia, and particularly social anxiety (Mathews & MacLeod, 1994; Mogg & Bradley, 2002).

Social anxiety is the fear of social situations implying evaluation and judgment by other people. More precisely, it concerns the fear to be judged and evaluated negatively, leading to a feeling of inadequacy, embarrassment and humiliation (Marcin & Nemeroff, 2003). Given the particular characteristics of this trouble and the specific role played by emotional facial

expressions (EFE) in human interactions, numerous studies have used EFE to evaluate biases in social anxious people, with the hypothesis of an attentional bias towards negative stimuli (Mogg & Bradley, 2002; Mogg et al., 2004).

Most studies on social anxiety have focused on two emotions, namely anger and fear (Mogg et al., 2004). The interest for these specific EFE can be easily understood if we consider that angry faces are universally read as a cue of interpersonal threat, whereas fear is an indirect signal, often interpreted by anxious patients as reflecting the presence of a threat in close environment (Fox, 2002; Surcinelli et al., 2006). Indeed, Öhman (1996) proposed that fear responses to biologically aversive stimuli as angry faces are mediated by automatic detection mechanisms, which act before consciousness and elicit autonomic responses.

Different studies using the probe-detection task in anxious populations have demonstrated a vigilance effect for threatening expressions as compared to neutral or positive faces (Mogg & Bradley, 1998, 2002). On the one hand, socially anxious participants shift their gaze more quickly towards threat faces than away from them (Mogg et al., 2004). On the other hand, they also display an avoidance of the eyes of angry faces, interpreted as a sign of the fear of social evaluation (Horley et al., 2004). Consequently, it seems that social anxiety is characterized by an hyperfunctioning alert system, with an attentional attraction for threatening stimuli.

Moreover, studies have illustrated a double movement in threatening faces processing, with an initial (attentional) bias towards threat cues, followed by an avoidance of these stimuli in later steps of processing (Mogg et

al., 2004). Those results support an hypervigilance-avoidance theory, implying that social phobic patients initially direct their attention towards threat-relevant stimuli, followed by avoidance that is thought to prevent objective evaluation and habituation. However, if socially anxious participants have a bias in perception and scanpath of threatening faces, it seems that they do not overevaluate the threat value of faces (Douilliez & Philippot, 2003; Philippot & Douilliez, 2005). In sum, though socially anxious people detect more easily threatening facial expressions, they do not seem to explicitly attribute a different meaning to these expressions.

Fear has always been interpreted as the key symptom of anxiety disorders (Woody & Tolin, 2002), but another emotion plays a crucial role in the aetiology and persistence of anxiety disorders: disgust is now recognised as particularly relevant in a wide range of anxiety disorders (Phillips et al., 1998b), including essentially specific phobia (phobic object often inspires a strong disgust to the subject, i.e. spider phobia, Charash & McKay, 2002; Woody & Tolin, 2002), but also obsessive-compulsive disorders (OCD) (Tsao & McKay, 2004) or agoraphobic avoidance (Muris, Merckelbach, Schmidt & Tierney, 1999). Lastly, Phillips et al. (1998) postulated a relationship between disgust and social phobia. This connection would be primarily based on self-directed disgust and shame, but also on the fear to be humiliated in public.

Indeed, Amir et al. (2003) have suggested that disgust could play a more prominent role than anger in social anxiety. Indeed, a face expressing disgust may evoke thoughts of being rejected and humiliated in public (Phillips et al., 1998b). Socially anxious people could be more susceptible to misread the non-

social expression of disgust, because of their negative anticipation in social contacts and evaluation. In addition, the fear of physical contact with unfamiliar people may also imply disgust, and, in the same time, enhance social fear.

To summarize, expressions of anger and disgust could be particularly critical in social anxiety, and the question of whether the expression of disgust may evoke an emotional bias in social anxiety has not been investigated yet. The present study will examine this point, by answering two main questions:

1. Are non-clinic socially anxious individuals more sensitive to categorical perception when compared to control participants? Do anger and disgust elicit attentional biases in non-clinic socially anxious subjects?

2. If we answer positively to this first question, where is located this deficit in emotional processing, at an attentional stage or later?

In order to address these questions, we used an emotional oddball paradigm, in which participants are confronted with series of frequent standard stimuli, and have to detect infrequent deviant stimuli (Campanella et al., 2002a; Campanella et al., 2004; Rossignol et al., 2005). By using a morphing procedure, continua of morphed faces moving from one facial expression (e.g. anger) to another one (e.g. disgust) were generated. So, we used as frequent stimulus a face displaying one emotion, and asked to detect two rare faces, the first one expressing the same expression at a different level of intensity, and the second one expressing another emotion. But the important point is that the deviant faces were always distant from the frequent one with a similar physical distance (30%). Moreover, the emotional

change was the only characteristic differencing rare and frequent stimuli. By this procedure, it could be established whether it is easier to discriminate disgust among angry faces, or the reverse, and if social anxiety modifies this pattern.

In order to study the temporal processing of information, the brain electrical activity related to the task was recorded and different specific ERP components were analyzed. Classical 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 defining the level of processing which is modulated by anxiety (Rossignol et al., 2005). Different specific ERP components are indeed produced when the participant has to detect, and to answer to rare stimulations. First, the N2b/P3a wave complex, known as representing an "attentional orienting complex" (Halgren & Marinkovic, 1995; Suwazono et al., 2000), is composed by the N2b component, maximally recorded at occipital sites around 250ms, and by the P3a recorded at frontal sites. More precisely, the N2b component refers to the attention switch needed to take a new information into account (Suwazono et al., 2000), and the P3a component is more sensitive to the degree of novelty of the deviant information (Knight, 1991). Second, the P3b component, peaking at parietal sites around 450ms, arises when an attended stimulus is detected (Bentin et al., 1999; Hansenne, 2000a), and should reflect decision making and premotor response-related stages (Hansenne, 2000a; Polich, 2004).

As separated functional processes are attributed to these components, an effect appearing on the N2b/P3a complex could be interpreted as an attentional modification of emotional processing, whereas a P3b alteration could reveal a response-related, conscious and elaborative bias. The timing of the modulations of these specific ERP components helps in interpreting the stage of processing at which the bias occurs (Campanella et al., 2004). Consequently, the study of the different ERP components evoked in response to the stimuli used in the present study should (1) give more information about the processing of emotional facial expression; and (2) allow defining more precisely the stage of occurrence of the processing bias in social anxiety.

## 2. Experimental procedure

### 2.1. Participants

Twenty students were selected based on their score on the Spielberger State and Trait Anxiety Inventory (STAI, Spielberger et al., 1983) and on the Fear of Negative Evaluation questionnaire (FNE, Watson & Friend, 1969) from a sample of 150 first year students from the University of Louvain. All participants were right-handed females, aged between 18 and 23 years, with normal/corrected vision, and without neurological disease or depression.

We defined cut-off score by median splits on standardised measure of anxiety (median: STAI-T= 50; STAI-S=52) and we chose the habitually used cut-off score of 19 for the FNE scale (see Douilliez & Philippot, 2003; Philippot & Douilliez, 2005). On these bases, we constituted two groups of ten participants: healthy control participants (HCP) and social anxious participants (SAP). Group characteristics are reported in Table 11.

**Table 11 : Mean Characteristics of the Samples (S.D. in parentheses).**

| | **Socially Anxious Participants** | **Healthy Control Participants** |
|---|---|---|
| **Age** | 20.60 (2.22) | 20.40 (1.95) |
| **Beck Score**** | 6.5 (1.84) | 2.2 (1.2) |
| **Staie**** | 59.20 (4.42) | 43.10 (4.17) |
| **Stait**** | 60.50 (7.57) | 41.95 (3.76) |
| **FNE **** | 21.00 (6.48) | 8.2 (3.43) |

** indicate mean differences between conditions ($p < .001$).

*t*-tests confirm that groups were not contrasted on age ($t(18)= -.214$, N.S.), but well and on anxiety level : SAP presented greater anxious trait ($t(18)= -6.936$, $p < .001$) and state ($t(18)= -8.376$, $p < .001$) than HCP.

Evidently, SAP also presented significantly more social anxiety ($t(18)= -5.522$, $p < .001$). Subjects equally differ on Beck Score ($t(18)= -6.143$, $p < .001$), but mean scores of the two groups remain lower to the clinical level of depression (defined by a cut-off score of 10 on the 13-items Beck Inventory Scale, see Furlanetto, Mendlowicz & Romildo Bueno, 2005), confirming that participants did not present depressive feature.

### 2.2. Stimuli

Faces of two actors (A, B), each portraying anger and disgust, were taken from Beaupré & Hess (2005).

Two continua of faces were created ('A Anger' to 'A Disgust', and 'B Anger' to 'B Disgust'), with four morphed faces for each continuum (see Campanella et al., 2000, for more details about morphing procedure). They were prepared by blending two faces in proportion 5:95 (i.e. 5% 'A Disgust' and 95% 'A Anger'), 35:65, 65:35 and 95:5. We will refer to them as 5, 35, 65 and 95% morphs along the appropriate continuum (i.e. AAD 5% refers to actor A, continuum Anger to Disgust, 5% 'A Disgust' and 95% 'A Anger") (See Figure 22).

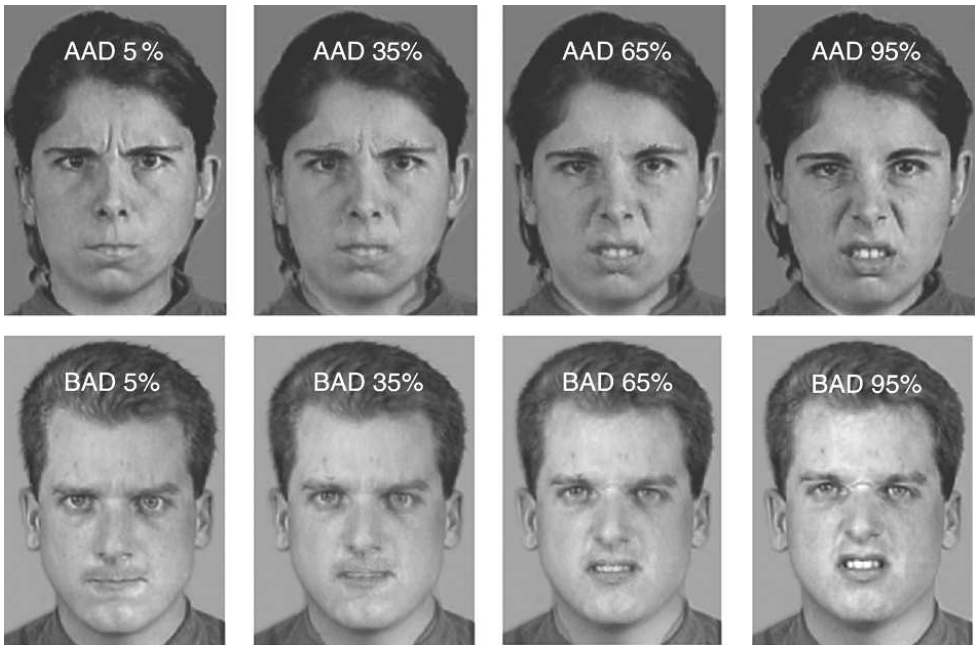


**Figure 22 : Illustrations of the morphed faces used in the experiment for the continua 'A anger to disgust' and 'B anger to disgust'.**

Pretests were realised on a group of twenty voluntary participants who had to identify whether the randomly presented images displayed a disgusted or an angry expression. Results showed that AAD 5% and BAD 5% were identified as presenting anger, whereas AAD 95% and BAD 95% were perceived as disgusted faces. Moreover, AAD 35% and BAD 35% were predominantly identified as anger, and AAD 65% and BAD 65% were referred as disgust. Based on these stimuli, four triads of stimuli were generated for the oddball paradigm. For instance, the triad AAD 5% - 35% - 65%, where AAD 35% constituted the frequent stimulus perceived as anger, and AAD 5% and 65% were the deviant stimuli, respectively identified as displaying the same emotion as the frequent stimulus (AAD 5% - rare WITHIN) or a different emotion (AAD 65% - rare BETWEEN). The three other triads were (1) BAD 5% (anger – rare WITHIN) – 35% (anger – FREQ) – 65% (disgust – rare

BETWEEN), (2) AAD 35% (anger – rare BETWEEN) – 65% (disgust – FREQ) – 65% (disgust – rare WITHIN), (3) BAD 35% (anger – rare BETWEEN) – 65% (disgust – FREQ) – 65% (disgust – rare WITHIN). With this method, the physical difference on the continuum separating the stimuli (30%) is constant across all trials.

Stimuli, sizing 6 cm horizontal and 8 cm vertical and subtending a visual angle of 3 x 4°, were presented during 500 ms one by one on a black background, and a black screen was displayed as intertrial interval, lasting randomly between 1300 and 1600 ms. Sixteen blocks were proposed, each defined by 100 stimuli (80 frequent stimuli; for instance: face AAD 35%; 10 deviant face AAD 5%, and 10 deviant face AAD 65%). The order of the sixteen blocks varied across subjects.

### 2.3. Recording

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 and were re-referenced by using a common average (Bertrand et al., 1985). 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 kΩ. EEG was continuously recorded (sampling rate 500 Hz, ANT software) and electrooculogram (VEOG) was recorded from electrodes placed on the supraorbital and 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 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. Data were filtered with a 30 Hz low-pass filter.

### 2.4. Procedure

The experiment took place between one and two weeks after the selection of the subjects. During the ERPs recording, participants sat on a chair in a dark room with their head placed 1 m from the screen and restrained in a chin rest. The participants had to point out as quickly as possible the occurrence of deviant stimuli by pressing a mouse button with their right index finger. They had 1500 ms to answer from stimulation onset. The entire experiment took approximately 50 minutes.

### 2.5. Data analysis

Two parameters were coded for every stimulus: (1) the type of the stimulus (rare Between Digust; rare Within Anger; rare Between Anger; rare Within Disgust; 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 (keypress for deviant stimuli, no keypress for frequent ones). This coding allowed to compute different averages of ERP target stimuli. The averages were made for each participant individually. For N2b, P3a and P3b

components, individual peak amplitudes and individual maximum peak latencies were obtained for the ERPs resulting from the subtraction of waveforms evoked by standard and deviant stimuli. Components were manually identified, peak-to-peak, on the basis of its latency range, topographical distribution and reproducibility from the median channels Oz, Fz and Pz (Campanella et al., 2004). Statistical analyses were computed with SPSS 12.0. We computed ANOVA with type of deviant trials (Between or Within) and emotion (Anger or Disgust) as within factors and group as between factor. Greenhouse-Geisser corrections were applied to within-subject comparisons. Paired Student *t*-tests were also used when appropriate. The alpha level of significance was set at 0.05 throughout.

## *3.* Results

### 3.1. Behavioural data

The performance was at 98% correct, and we computed a 2 x 2 x 2 ANOVA on reaction time for correct responses, with condition (Between vs Within) and emotion (Anger vs Disgust) as within factors, and groups (HCP or SAP) as between factor.

The results showed a main effect of the condition ($F(1, 18) = 37.513$, $p < .001$), meaning that all participants responded quicker to Between trials (see Figure 23), replicating the classical effect of categorical perception. Second, two interaction effects emerged: the first one, between condition and emotion ($F(1,18) = 6.398$, $p = .021$), reflects a faster detection of Between trials displaying Disgust (and interrupting a train of angry faces) ($t(19)=3.131$, $p =.005$) compared to Anger, together with comparable detection of Anger and Disgust on Within condition ($t(19)=.662$, *ns*).

Next, a triple interaction between condition x emotion x group ($F(1, 18) = 5.252$, $p = .034$) indicated a modulation by anxiety of categorical perception, that we explored by subsequent post-hoc tests : if HCP showed the interaction between condition and emotion described above ($F(1, 9) = 30.044$, $p <.001$), SAP displayed the opposed pattern ; in this group, there were no interaction effects ($F(1, 9) = .018$, *ns*), nor emotion effect ($F(1, 9) = 3.824$, N.S.) but only the classical effect of condition ($F(1, 9) = 7.313$, $p = .024$), similarly than HCP ($F(1, 9) =75.229$, $p <.001$).

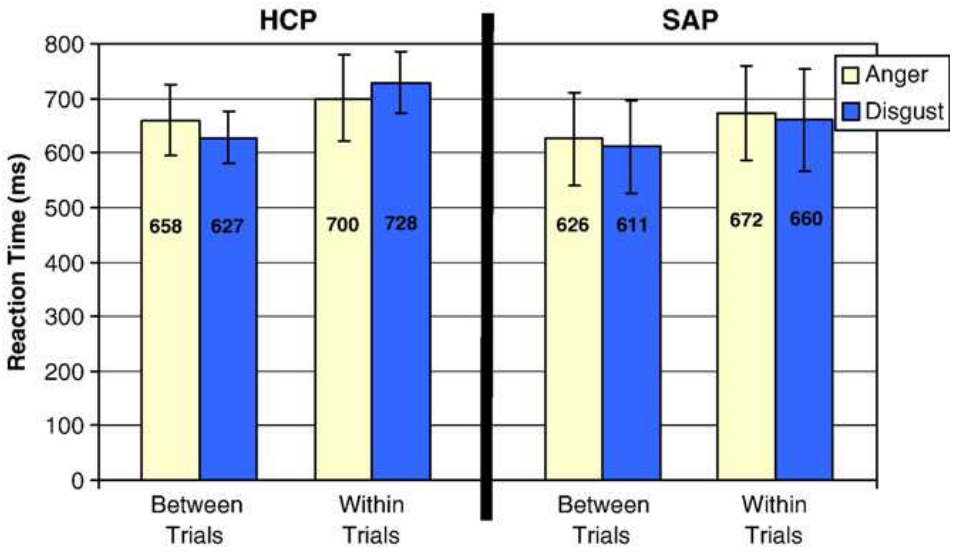


**Figure 23 : Reaction times in detection of deviant faces.**

### 3.2. Event-related Potentials

Figure 24 illustrates the ERP waveforms obtained for frequent and deviant stimuli. As classically described in the literature, two main components can be observed when ERPs evoked in response to frequent stimuli are subtracted from those obtained in response to deviant ones: (1) the N2b component, recorded around 250 ms at occipital site, and reversing polarity at frontal level yielding the P3a wave, and (2) the P3b component, recorded at parietal site around 450ms and reflecting response preparation and closure process.

ANOVAs 2 (conditions) x 2 (emotions) x2 (groups) were computed on each component. They showed that BETWEEN trials always evoked earlier ERP component (see Table 12 and Figure 26).

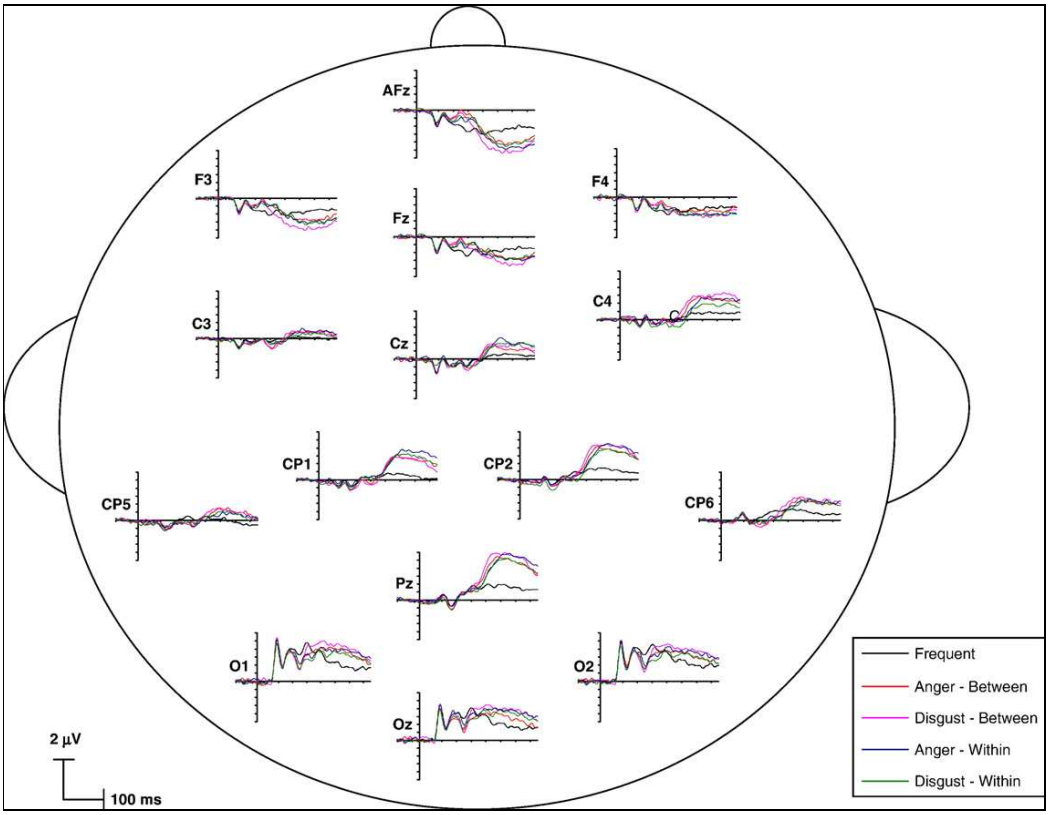


**Figure 24 : Illustration of grand averaged ERPs elicited by standard (black bold line) and deviant stimuli (thin lines) in SAP, for a subset of 15 channels. Negative is down.**

### 3.2.1. N2b component

The analysis on N2b disclosed main effect of condition in latency ($F(1, 18) = 41.04$, $p > .001$), and Conditions x Emotions x Groups interaction on amplitude ($F(1,18) = 6.58$, $p = .019$) (see Figure 25).

Complementary analyses were performed in order to decompose this complex interaction effect. In HCP, Anger and Disgust evoked N2b of similar amplitude in the WITHIN condition ($t(9)=-.123$, N.S.), whereas Disgust tended to evoke larger N2b than Anger detection in the BETWEEN condition ($t(9)=1.999$, $p=.077$), as if it required more attentional resources to

detect an expression displaying disgust amongst a train of angry faces than the reverse.

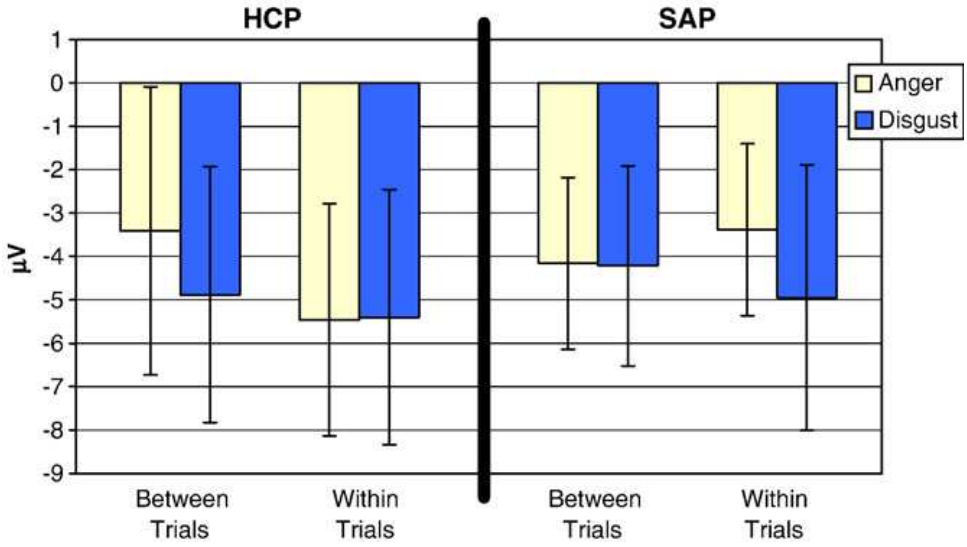


**Figure 25 : Amplitude effects on N2b component related to the level of social anxiety.**

However, SAP showed a different pattern. Indeed, Anger and Disgust elicited comparable N2b in the BETWEEN condition ($t(9)=.102$, N.S.), but disgusted faces tended to evoke enhanced N2b as compared to angry ones in the WITHIN condition ($t(9)=2.011$, $p=.075$). Moreover, if we compare neural responses to Angry faces in the WITHIN condition, HCP tended to produce enhanced N2b in response as compared to SAP ($t(18)=-1.971$, $p=.064$).

Indeed, Disgust detection in both conditions is comparable in SAP and HCP (*t*-tests values were equal to .552 and .337 for BETWEEN and WITHIN conditions, respectively), but anxious produced a diminished N2b in response to a change of level in an expression of anger (WITHIN condition) than control participants.

### 3.2.2. P3a component

P3a latency was equally influenced by the condition ($F(1,18) = 46.313$, $p < .001$) and appeared shorter for BETWEEN trials.

A group x emotion effect ($F(1,18) = 3.847$, $p = .065$) was tendencial : control and anxious participants did not differ on P3a latencies for Anger ($t(18) = .342$, N.S.), but SAP produced earlier P3a for Disgust ($t(18) = 2.132$, $p = .047$).

**Table 12 : N2b, P3a and P3b components: Latency (ms) and amplitude (µV) for the different types of trials.**

| | | | SAP | | HCP | |
|---|---|---|---|---|---|---|
| | | | **Latency** | **Amplitude** | **Latency** | **Amplitude** |
| **Between trials** | **Anger** | **N2b** | 300 (22.00) | -4.16 (1.98) | 308 (28.00) | -3.41 (3.32) |
| | | **P3a** | 312 (23.42) | 3.75 (2.28) | 314 (28.42) | 2.79 (2.02) |
| | | **P3b** | 531 (49.8) | 7.84 (4.76) | 538 (40.24) | 6.99 (2.32) |
| | **Disgust** | **N2b** | 307 (21.40) | -4.22 (2.30) | 300 (46.33) | -4.88 (2.95) |
| | | **P3a** | 298 (23.27) | 4.06 (2.30) | 323 (33.4) | 3.13 (1.58) |
| | | **P3b** | 522 (33.18) | 9.07 (4.95) | 525 (37.14) | 8.37 (2.71) |
| **Within trials** | **Anger** | **N2b** | 324 (30.20) | -3.38 (1.98) | 331 (31.71) | -5.46 (2.68) |
| | | **P3a** | 328 (34.70) | 3.39 (1.53) | 335 (31.68) | 3.07 (1.30) |
| | | **P3b** | 561 (52.67) | 7.65 (3.72) | 572 (42.48) | 5.96 (2.79) |
| | **Disgust** | **N2b** | 320 (26.76) | -4.95 (3.06) | 318 (45.18) | -5.40 (2.83) |
| | | **P3a** | 318 (29.15) | 3.84 (1.91) | 349 (33.74) | 2.70 (1.77) |
| | | **P3b** | 546 (32.07) | 7.67 (4.08) | 523 (113.18) | 5.62 (2.29) |

### 3.2.3. P3b component

The conditions influenced latencies ($F(1,18) = 6.541$, $p = .02$) and amplitude ($F(1,18) = 14.212$, $p < .001$) of the P3b component, which appeared earlier and enhanced for BETWEEN trials. A Condition X Emotion interaction ($F(1,18) = 4.677$, $p = .044$) was also revealed on P3b amplitude :

Anger and Disgust detection evoked similar P3b amplitude in the WITHIN condition ($t(19)=.313$, N.S.), but P3b was enhanced for Disgust in BETWEEN condition ($t(19)=2.794$, $p=.012$).

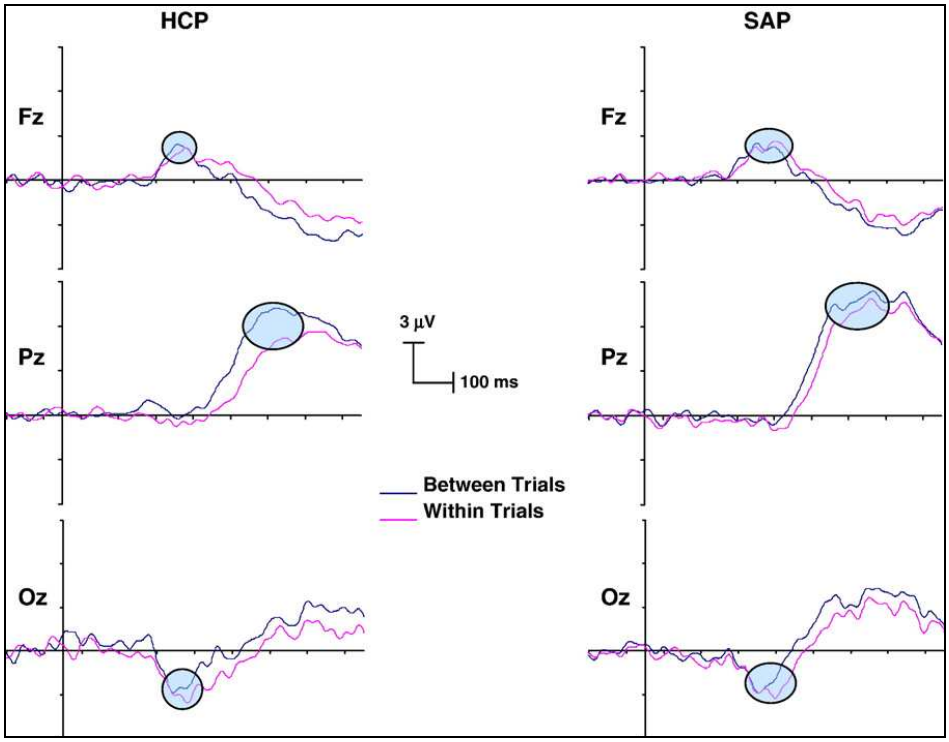


**Figure 26 : Representation of categorical perception effects on ERP waves, in SAP and HCP groups. Blue lines represent BETWEEN condition, and pink lines WITHIN condition. The shaded areas indicate the peaks studied, namely the N2b on Oz, the P3a on Fz and the P3b on Pz.**

## 4. Discussion

The categorical perception effect on emotional recognition has been described as an attention-related phenomenon (Campanella et al., 2002a). Authors have reported important modifications of attentional mechanisms in anxiety disorders, and alterations of emotional perception, together with perception biases (Bradley et al., 1999; Mathews & MacLeod, 1994). Consequently, the aim of this study was to assess the categorical perception of anger and disgust in a sample of participants presenting sub-clinical social anxiety, and to identify the level of cognitive processing responsible for eventual perception biases. More precisely, we examined whether social anxiety symptoms influence the categorical effect evoked by deviant stimuli during emotional facial expression detection, at a behavioural level, and at the neurophysiological level through the N2b/P3a complex.

Firstly, the classical effect of categorical perception was reproduced: Between trials were easier to detect than Within trials, and gave rise to shorter reaction times. Therefore, participants discriminated more quickly faces perceived as displaying different expressions than faces perceived as presenting the same expression, even if the physical difference between the two faces was constant (Campanella et al., 2002b; Etcoff & Magee, 1992). This behavioural result was sustained by an earlier N2b/P3a complex elicited by Between trials, and by an earlier and enhanced P3b component. These results, replicating those of Campanella et al. (2002a), confirm that the discrimination

performance is more affected by category membership than by objective physical distance.

Second, our main result is the effect of social anxiety on categorical perception observable on ERP components. Indeed, at a behavioural level, SAP did not detect more quickly than HCP deviant trials amongst frequent ones, and they show comparable P3b decisional component with those of HCP. This effect is not consistent with the classically reported observation of an accelerated detection of change in anxiety (Mialet, 2000; Rossignol et al., 2005). However, studies reporting a faster detection of negative emotions in anxiety have often used negative emotional stimuli in contrast to neutral or positive stimuli (Bertrand et al., 1985; Fox, 2002; Rossignol et al., 2005). In the present experiment, frequent stimuli were already emotional, and the change to be detected only concerned a level of intensity (Within trials), or a change from a negative emotion to another one (Between trials). This key difference in experimental paradigm might explain the absence of behavioural effect related to anxiety level.

In contrast, non-clinical social anxiety seems to act on specific emotional processing, even in a behavioural level: HCP detected faster Disgust amongst Angry faces than the contrary, but SAP did not show any comparable difference. Moreover, electrophysiological results showed clear effects of sub-clinical features of social anxiety on the temporal course of cognitive processing elicited by frequent and deviant stimuli. The N2b component, related to the attentional resources devoted to orient the attention toward

new information, was particularly influenced by non-clinical social anxiety. So, for Between trials, when the deviant stimuli displayed an emotion perceived as different from the frequent ones, SAP elicited comparable N2b for disgust and anger detection, whereas HCP tended to produce increased N2b in response to disgust, as compared to anger detection. On the other side, the pattern is reversed for Within trials: when the emotion displayed by the deviant stimuli is the same than the frequent one, but at a higher level of intensity, HCP produced similar N2b for disgust and anger detection, when SAP evoked a reduced N2b for anger as compared to disgust detection. In this Within condition, responses to disgust presented similar amplitude and latency parameters in both groups for, but the N2b corresponding to anger detection tended to be smaller in social anxious subjects.

If we consider that the N2b wave elicited in HCP corresponds to the attention switch classically needed to consider a deviant stimulus, and to the amount of attentional resources devoted to this processing (Halgren & Marinkovic, 1995), we propose that attentional load and engagement may explain the divergent effect of non-clinical social anxiety. Since higher amplitudes are often interpreted as a cue reflecting a deeper processing (Rugg & Coles, 1995), our results suggest that SAP detect more easily than HCP a change in a same expression of anger (Within trials), because of their particular worries. In this task, rare stimuli in Within trials depicted more intensely the target emotion (for instance, AAD 5% and 35% were respectively rare and frequent stimuli). If the degree of anger expressed by a

face increases during a conversation, it means that the threat represented by the person is rising, and that counter-measures must be taken.

The efficient observation of such subtle changes is particularly critical in social anxiety. When SAP have to detect a change in the degree of anger displayed by a face, it seems they have less difficulties to disengage their attention from the frequent stimuli (already displaying anger, but less intensively). Consequently they will need less attentional resources, and the resulting N2b will be smaller. These results are consistent with the hypothesis of an enhanced ability to detect negative social cues in patients with a high FNE score (Winton, Clark & Edelmann, 1995). On the other hand, evaluating a change in the degree of disgust depicted by a face may seem less relevant, and SAP group needed more attentional resources to disengage from the frequent stimuli and detect the infrequent ones. This effect is equally observable on the P3b component, which appears enhanced for disgust as compared to anger, as if two expressions of disgust with different intensity were less differentiable than the two expressions displaying anger, with an equal physical difference.

For Between trials, the problem is reversed: HCP tended to produce smaller N2b when they have to detect angry faces amongst a train of disgusted ones, as if this task was easier, and thus required less attentional resources, than to detect disgust amongst angry faces. In this last situation, people need more attentional resources to disengage from faces depicting anger, and consequently evoke an enhanced N2b. This observation sustains

the notion of the high relevance of anger expression, even in non anxious individuals (Morris et al., 1996; Öhman, 1996). However, SAP evoked similar N2b for anger and disgust detection, and allocated the same attentional resources to disengage from frequent faces displaying disgust in order to detect angry faces than the reverse, as compared to HCP. They did not show the facilitation effect displayed by HCP when they have to disengage to disgust in order to detect rare faces expressing anger, and it could be interesting to check in further studies whether SAP subjects would show specific difficulties to disengage from disgust.

Spatial attention competences implicated in our task justify our interest for engagement and disengagement theory. Posner and collaborators studied spatial attention and described two subjacent mechanisms (Amir et al., 2003): facilitation and inhibition. When a cue is presented, subjects direct their attention towards its spatial location, and decrease the processing of other locations. Moreover, subjects have to interrupt the ongoing activity, and to disengage attention from the present stimulus, in order to move attention towards the new location and reengage to this new stimulus (Amir et al., 2003). However, as recalled by Marcin & Nemeroff (2003), SAP have a distorted mental self-image, and focus their attentional resources towards stimuli likely to elicit negative evaluation. Consequently, when a face displaying anger appears after a face expressing disgust, we hypothesised that anxious individual may be in a situation of conflict: on one hand, anxiety is characterized by the focus of attention towards threatening information (Marcin & Nemeroff, 2003; Mathews & MacLeod, 1994), and anger should

attract subject's attention; on the other hand, the stimulus reflecting the most negative evaluation is the face expressing disgust (Amir et al., 2005). So, the subjects have to disengage their attention away from faces expressing disgust to orient it towards angry faces.

A previous study already outlined difficulties to disengage attention in social phobia (Amir et al., 2003). In this latter study, socially relevant threat words, positive words and neutral words were presented one by one on a screen, with two possible locations. After the disappearance of the word, participants had to detect a probe presented in one of these two locations (i.e. variation of the Posner paradigm). Results showed difficulties of disengaging from threat-related words in individuals with social phobia.

An intriguing point is that, in our study, we observed comparable behaviour (similar N2b amplitude) when SAP had to disengage from frequent disgusted or angry faces in order to orient attention towards rare faces expressing anger or disgust. The reason may be the increased pertinence of disgust expression in social anxiety, as compared to anger. Further studies should investigate this question.

In current literature, disgust recognition has been frequently studied without interest for its specificity in anxious disorders. As underlined by McKay (2002, p.475) in its editorial of a special issue devoted to disgust, "the state of the research on disgust and its role in anxiety problems is still in its infancy". For example, Surcinelli et al. (2006) asked to high vs. low trait anxious participants to evaluate angry, sad, happy, fearful, disgusted and

neutral faces, and only observed a better recognition of fear in high anxious individuals. This study evaluated conscious, verbal evaluation, in which social anxious people do not seem altered (Douilliez & Philippot, 2003; Philippot & Douilliez, 2005), and did not bring information about disgust perception. In the same way, studies investigating visual scanpath (Horley et al., 2004) or attentional processing (Mogg & Bradley, 2002; Mogg et al., 2004) often compared angry faces to happy or neutral faces, without consideration for disgust perception. Nevertheless, a recent study using functional magnetic resonance imaging has outlined an hyperactivation of the anterior cingulated cortex when subjects with social phobia perceived disgusted faces Amir et al., 2005. These authors concluded to a stronger sensation of disgust experienced by social anxious individuals when they see disgusted faces, as compared to subjects without this specific anxiety. This example illustrates the importance to concentrate the research upon the specificity of disgust.

To our knowledge, our study is the first to compare the processing of anger and disgust emotional faces-stimuli in a sample of participants with non-clinical features of social anxiety, using an emotional oddball paradigm. However, our data are still preliminary: since the participants were only sub-clinical and selected according to criteria's of FNE and STAI, they were not grouped according to a clinical diagnosis. As a consequence, these participants should only be considered as normal subjects with social anxiety tendencies, with a sub threshold degree of symptom severity. Moreover, our analyses were computed on two groups composed by 10 individuals each, and we used

faces of only two actors as stimuli. Further studies should confirm these data in larger clinical samples, and with extended sets of stimuli.

To conclude, this study has underlined the particular status of anger and disgust in non-clinical social anxiety. First, socially anxious individuals are more able than healthy individuals to direct their attentional resources towards a light change in a face expressing anger; second, they did not show the same facilitation than healthy individuals when they have to disengage from faces expressing disgust in order to detect anger. All these differences arise at an attentional level, and are counterbalanced by decisional processing, leading to an altered behavioural performance: High anxious individuals detect differently that control subjects changes involving disgust or anger, in within as well as in between category judgments, displaying a modulated categorical perception effect.

## Introduction à la troisième question de recherche

Notre deuxième question de recherche visait à étudier si certaines émotions faisaient l'objet d'un traitement particulier dans l'anxiété sociale.

Notre choix s'est porté sur les émotions de colère et de dégoût, et les données présentées ci-dessus démontrent que le traitement de ces émotions est à tout le moins perturbé chez les sujets démontrant une anxiété à la fois générale et sociale. Une question s'impose donc comme une évidence : qu'en est-il de sujets souffrant certes d'anxiété sociale, mais non pas d'anxiété générale ? Autrement dit, quand la source de l'anxiété provient exclusivement de la prééminence d'interactions interpersonnelles, et quand le visage et ses différentes affirmations émotionnelles sont au centre des préoccupations, qu'en est-il du traitement émotionnel ?

L'étude présentée dans le chapitre 5 propose déjà des pistes de réponse quant à ces questions, en démontrant des modulations précoces du traitement visuel, observable dès 100ms après la présentation du stimulus, ainsi qu'une évaluation émotionnelle plus précoce des stimuli négatifs chez les sujets souffrant d'anxiété sociale en l'absence d'anxiété-trait. Cependant, cette étude se basait sur un paradigme oddball de détection de déviance, et ne permettait pas de contrôler les mécanismes attentionnels définis par Posner comme sous-tendant l'attention visuo-spatiale.

Un paradigme semblait tout désigné pour étudier ces processus, à savoir le paradigme de détection de cibles. Ce paradigme *dot-probe* avait permis à de nombreuses études de mettre en évidence un phénomène de vigilance envers la menace : parmi elles, pratiquement toutes les études de Mogg et Bradley

classiquement référées dans ce domaine, et à leur suite celles d'Elaine Fox (Fox et al., 2001; Fox et al., 2002). Alors que les premières études s'attardaient sur le phénomène d'engagement attentionnel et d'orientation facilitée vers les cibles succédant aux stimuli de valence négative, ces dernières avaient quant à elles abouti à l'hypothèse de perturbations du processus de désengagement. A leur suite, d'autres données avaient confirmé cette hypothèse (Koster et al., 2004; Koster et al., 2006; Salemink et al., 2007b), et des controverses passionnées entre les défenseurs d'une orientation facilitée et ceux d'un désengagement défaillant s'étaient développées, conduisant même à une remise en question de l'utilité de ce paradigme par les auteurs l'ayant le plus louangé jusque là (Mogg et al., 2008).

Cependant, à la même époque, l'utilité d'un enregistrement électrophysiologique durant l'accomplissement de cette tâche avait été suggérée (Perchet & Garcia-Larrea, 2000, 2005; Perchet et al., 2001), et une étude chez des sujets contrôles fournissait des données quant au timing des opérations cognitives aboutissant à la production d'un biais envers les visages menaçants (Pourtois et al., 2004). Il nous semblait donc opportun de tester si nous pouvions objectiver les mécanismes attentionnels à l'œuvre lors de la réalisation d'une tâche de type dot-probe au moyen de la technique des potentiels évoqués, avec pour question l'implication des processus d'engagement et de désengagement attentionnel.

Pour répondre à ces questions, deux études ont été conçues en complémentarité[16]. La première offrait d'étudier les corrélats électrophysiologiques sous-tendant la réalisation d'une tâche dot-probe classique, et sera présentée dans le chapitre 7.

La seconde étude (chapitre 8) proposait de vérifier l'intégrité du processus de désengagement attentionnel en ne fournissant qu'un seul indice latéralisé. En effet, Fox avait proposé que la présentation simultanée de deux indices, neutre et émotionnel, pouvait occulter la difficulté éprouvée par les individus anxieux à désengager leur attention du stimulus émotionnel. Notre principale hypothèse portait donc sur des patterns de résultats comportementaux et électrophysiologiques différents dans les deux études envisagées ensemble, puisque celles-ci impliquaient des processus attentionnels contrastés.

Dans la mesure où l'anxiété-trait modulait les étapes de production d'une réponse motrice dans notre première étude (chapitre 4), nous avons sélectionné des participants présentant une anxiété sociale isolée. En nous basant sur les observations de Fox (2004), nous postulions des difficultés de désengagement se manifestant par un ralentissement des temps de réaction

[16] Deux articles en préparation retracent la mise au point de ces études, le premier étant consacré à la comparaison de tâches demandant une localisation ou une discrimination de l'indice (Rossignol, Campanella, Bissot & Philippot, En Préparation), et la seconde comparant les corrélats électrophysiologiques de la présentation d'un indice latéralisé versus deux indices séparés par une croix de fixation centrale (Rossignol, Philippot, Bissot & Campanella, En Préparation).

des sujets anxieux sociaux pour la détection de cibles incongruentes succédant à la présentation de visages négatifs, et des corrélats électrophysiologiques démontrant des différences d'activation dès les étapes précoces du traitement des visages, en nous basant sur les résultats rapportés dans le chapitre 5. Ces difficultés de désengagement devraient être particulièrement saillantes dans le cas de cibles non-valides succédant à un seul indice latéralisé.

# Chapitre 7 :

# Rôle respectif des processus d'engagement et de désengagement attentionnels

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Social Anxiety induces early modulations of face processing during an overt emotional cued-target paradigm

Biological Psychology, Soumis.

## Abstract

The cued-target paradigm has been extensively used to demonstrate emotional biases in clinical and sub-clinical anxiety. However, the cognitive timing of this phenomenon remains widely unknown. This study aimed at investigating the processing of neutral-emotional pairs of faces in sub-clinical social anxiety, and to explore how the subsequent processing of targets can be modulated by cues emotional load. Socially anxious participants performed a modified dot-probe task and demonstrated (a) increased N100/P100 complex and N170 wave to face pairs, especially for neutral-anger and neutral-fear pairs, (b) an amplified emotional appraisal (N300), particularly for pairs involving anger and disgust, (c) a reduction of N100/P100 complex to probes, particularly for targets replacing neutral as compared to emotional faces. These results suggest an enhanced processing of faces pairs, affecting the subsequent processing in the sense of vigilance to the location of emotional faces and difficulties to disengage from them.

## 1. Introduction

Evidence of a preferential processing of emotional stimuli has been widely supported in recent literature (for a review, see Vuilleumier, 2005). Notably, behavioural and neuroimaging studies have demonstrated that negative pictures such as fearful or angry faces attract attentional resources rapidly and involuntarily (Morris et al., 1996; Pourtois & Vuilleumier, 2006b).

Among the different paradigms developed to study emotional attention, the "cued"-paradigm or visual dot probe task, stemming from Posner's works (Posner & Petersen, 1990), is one of the most familiar. In that task, pairs of stimuli briefly appear at two different spatial locations on a screen. After their offset, a probe appears at one of these two locations. The allocation of attention is measured by the time needed to respond to the probe, with the hypothesis of a quicker detection of probe located where attention was already directed. Authors developed an emotional version of that task to investigate attentional deployment toward emotional material (see for instance MacLeod et al., 1986), and the common method consists in using a neutral and an emotional stimulus as cues. In that frame, the target may appear either at the location of the emotional stimulus (giving rise to a congruent presentation, since one might expect that attention is driven towards the emotional cue), or at the location of the neutral stimulus (incongruent presentation). Various versions of this task were developed, using words as cues (Mogg et al., 1997; Vassilipoulos, 2005), before some authors hypothesized a stronger attraction for pictorial stimuli, as for example emotional facial expressions (Beall &

Herbert, 2008; Mogg & Bradley, 2002). Studies demonstrated attentional bias towards threat in healthy populations, that is a facilitated processing of targets replacing threatening stimuli, which attract attentional resources towards their locations (Pourtois et al., 2004; Santesso et al., 2008 ; see also Bar-Haim et al., 2007 or Frewen et al., 2008 for a discussion).

Such attentional biases might be enhanced in anxiety and more specifically in social anxiety, since that pathology has been characterized by abnormal processing of social information, particularly conveyed by faces (Rapee & Heimberg, 1997). A large body of behavioural studies has pointed to the enhanced detection of threat-cues in social anxiety. Anxious people show increased orienting and sustained attention towards threat stimuli in the visual search paradigm (Gilboa-Schechtman et al., 2005) as well as in "dot-probe" paradigm (Mogg & Bradley, 2002; Mogg et al., 2004). This interpretation is based on the observation of increased attention to the location of threatening faces in dot- probe tasks, leading to increased detection of targets that appear in these locations (Bradley et al., 1998; Fox, 2002; MacLeod et al., 1986; Telzer et al., 2008).

However, an alternative hypothesis has been formulated and postulates avoidance of faces (Mansell et al., 1999). For instance, Chen et al. (2002) reported that patients with social phobia were faster to identify a probe occurring in the location of a household object than of a face, regardless the emotional expression displayed. This reduced processing of social indicators would contribute to the development and maintenance of anxiety disorders.

A mixed model has been developed to reconcile these contradictory results: Social anxiety would be characterized by an initial vigilance followed by an strategic avoidance of emotional stimuli (Mogg et al., 2000a). In this context, the use of long-time presentation would be characterized by avoidance of emotional faces, while short presentation time would reveal the influence of the process of hypervigilance (Mogg et al., 2004).

Moreover, the bias is supposed to have an attentional origin, but the differential implication between attentional processes of engagement and disengagement has been outlined (Fox et al., 2001). Indeed, in the case of incongruent presentation, subjects have to *disengage* from location of the cue, moving to the location of the target, and to *engage* in this new location. Consequently, the facilitated responses to valid probes following threat cues may arise from difficulty to disengage from threat location, rather than vigilance to threat (Koster et al., 2004). To resolve this issue, comparisons between responses in valid and invalid trials have been proposed to measure difficulties to disengage from threat and fast orienting towards threat (Koster et al., 2004). In this frame, slower responses to target replacing invalidly threatening-cues targets indicate disengagement difficulties, while faster responses to validly threatening-cues targets reflect faster engagement. In accordance with that theory, some authors observed no facilitation effect on valid threat trials, which implicate the engagement process, but an emotional modulation by invalid cues (Fox et al., 2001; Fox et al., 2002; Yiend & Mathews, 2001). However, the indications derived from behavioural studies, as for instance reaction time or response accuracy, do not allow to elaborate

precise hypotheses about the neural bases of response production. For instance, a reponse delay may be attributed to an impaired orienting, a disrupted disengaging, a strategic avoidance, or to a combined influences of these three processes (Koster et al., 2006). Finally, the exact involvement of perceptive, attentional, or response-preparation cognitive processes remain widely unknown, as the timing of biases appearance during cognitive processing.

Due to their excellent temporal resolution, event-related potentials (ERPs) can provide some insight about the timing of processing biases occurrence in emotional perception, and notably in anxious states. Therefore, electrophysiological correlates of dot-probe paradigms have recently been investigated in healthy population. It was observed that the presentation of facial expression of fear or anger increases neural response in extrastriate visual areas, resulting in an enlarged P100 in response to targets following these stimuli (Pourtois et al., 2004; Pourtois et al., 2005; Santesso et al., 2008). These data have been interpreted as a sign of increased attention to visual signals of threat in healthy individuals (Vuilleumier & Pourtois, 2007).

However, only few studies have approached the question of electrophysiological bases of emotional processing in social anxious disorders. Some reports indicated increased P100 in response to emotional faces without specificity, as well as an enhanced N170 wave when social phobic patients have to identify angry faces (Kolassa & Miltner, 2006). In an oddball paradigm involving categorical perception with morphed faces varying from disgust to anger, socially anxious subjects evoked a decreased N2b when they had to

detect deviant faces displaying more intense expression of anger, but an enhanced N2b to detect angry faces appearing amongst disgusted faces (Rossignol et al., 2007). These results suggest an increased attention to features of angry faces but also difficulties to disengage from faces displaying disgust. Lately, the P300 component has been described as enhanced in response to angry faces (Moser et al., 2008; Sewell et al., 2008) and interpreted as reflecting the particular relevance of that emotion in social anxious disorder. As a consequence, the examination of these particular ERP components could highlight the presence of particular processing biases, notably related to engaging/disengaging states.

Very recently, a study investigated the neural bases of performances of social phobic patients in a dot-probe paradigm coupled with a go/no go task (Mueller et al., 2008). Authors reported enhanced P100 amplitudes and fusiform gyrus activation to angry-neutral vs happy-neutral face pairs in social phobia, and decreased P100 amplitude to probes succeeding to emotional as compared to neutral faces. These results were interpreted within the framework of vigilance/avoidance theory, as the sign of an increased early vigilance to faces, followed by a reduced visual processing of emotionally salient locations at later stages of cognitive processing.

To our knowledge, these results are the first trying to evidence neurophysiological processes reflecting orienting towards threat. That study considered only angry faces, but fear has also been described as leading to emotional biases (for a review, see Douilliez & Philippot, 2006). Moreover, a relatively rarely studied emotion, disgust, may also lead to such biases (Amir

et al., 2005; Rossignol et al., 2007), and the question of how anxious people resolve the competition between these three emotions when they are presented in a same task, has not been investigated yet. Indeed, most of the studies only compared positive and negative facial expressions, and concluded to faster orienting towards threat without envisaging the potential division of attentional resources required by the processing of several negative emotions. However, Calvo and Nummenmaa (2008) have reported that the direction of biases may be modulated by that kind of competition. Moreover, that modulation might be specially enhanced in social anxiety, since that trouble has been characterized by a increased attention to faces (Mogg & Bradley, 2002).

Consequently, we investigated whether sub-clinical social anxiety (a) amplifies attentional biases (Pourtois et al., 2004; Santesso et al., 2008), (b) leads to similar avoidance of emotional-cues location as the one observed in social phobic patients (Mueller et al., 2008), and (c) modulates the processing of different emotions in competition. The electrophysiological correlates of processing of pairs of emotional faces in a classical dot-probe paradigm were recorded. Participants had to discriminate, after a brief presentation of a face pair, the direction of a small arrow presented at the location previously occupied by one of the faces. In order to control the extent of eventual attentional biases, different disgusted, happy, fearful or angry emotional faces were presented together with a neutral face (of similar identity).

We assume that modulations of emotional processing would appear in ERP components directly associated with faces processing, and the waves

N100, P100, N170 and N300 will be examined. Amplified perceptive processing of faces should lead to increased N100 and P100 waves, the modulation of processing characteristics of faces to an increase of the N170, and a modification of emotional appraisal to a enhanced N300 component. The verification of these assumptions would lead to conclude to an hypervigilance towards faces in social anxiety. In contrast, reduced amplitudes would reflect avoidance of these faces. Then, we will explore the modulation of attention after face offset. To this aim, we examine the ERP components associated with targets following facial cues. Increased amplitudes of the complex N100/P100 in response to the targets would outline a sustained hypervigilance, when decreased amplitude rather would reflect a later avoidance. The comparison between the valid and invalid condition should also help clarify the concepts of engagement towards, and disengagement from threat.

These electrophysiological cues will be compared to behavioural performances, reaction time and response accuracy. Longer reaction time to probe replacing emotional faces would reflect avoidance, while shorter response latencies should indicate hypervigilance. These cues will equally be correlated with P300 parameters, in order to derive information about closure mechanisms and response-production processes, and N300 which has been described as responding specifically to emotional load of visual stimuli (Carretié et al., 1997b; Schutter et al., 2004)

## 2. Materials and methods

### 2.1. Participants

Thirty participants were pre-selected based on their score on the Spielberger State and Trait Anxiety Inventory (STAI, Spielberger et al., 1983) and on the Fear of Negative Evaluation questionnaire (FNE, Watson and Friend, 1969; see Musa, Kostogianni & Lepine, 2004 for French properties) from a sample of students from the University of Louvain. Four participants had to be excluded because of artifacts during ERP recording, so that twenty-six participants remained in the sample. All participants were right-handed, between the ages of 18 and 25 years, with normal/corrected vision, and without neurological disease or depression.

Since our aim was to contrast groups exclusively on social anxiety, we selected participants with low score to Beck Inventory (Beck & Beamesdefer, 1974), normal scores on STAI-A and B, but low or high score to FNE scale. The presence of social anxiety was based on a FNE score above 19 (for a discussion about the cut-off score of the FNE scale, see Douilliez & Philippot, 2003) and, to ensure a contrast on this scale, healthy participants had to report a score below 10. On these bases, we created two groups of thirteen participants: healthy control participants (HCP) and social anxious participants (SAP). Group characteristics are reported in Table 13.

**Table 13: Mean scores (and standard deviations) for questionnaire measures of State-Anxiety (STAI-A), Trait-Anxiety (STAI-B), Social Anxiety (FNE) and depression (BECK)**

| | Age | Ratio male/female | STAI-A | STAI-B | FNE | BECK |
|---|---|---|---|---|---|---|
| **SAP (N=13)** | 21.2 (1.8) | 2/11 | 49.8 (4.9) | 48.9 (4.3) | 23.6 (3.4) | 3.4 (2.6) |
| **HCP (N=13)** | 22.8 (2.6) | 5/8 | 48.4 (6.8) | 45.7 (4.3) | 8.7 (1.6) | 1.9 (2.2) |

## 2.2. Material and procedure

### 2.2.1. Materials

The stimuli set comprised 30 grey pictures of six different individuals (3 males and 3 females) each posing neutrality, anger, disgust, happiness and fear, taken from the database elaborated by Beaupre and Hess (2006). After being trimmed to exclude non-facial contours and hair, each facial stimulus was enclosed within a rectangular frame measuring 4x6cm, subtending 4.7° x 8.5°. Face stimuli were presented by pairs including a neutral face and an emotional portrait of the same individual (depicting happiness, anger, disgust or fear).

The target stimulus was a white arrow pointing up or down, sizing 2cm (visual angle: 2.86°) and presented against a black background. The target was always presented unilaterally, on either the left or the right visual field (the type of probe, up or down, and the location of the probe, left or right, were counterbalanced through the task), at the location of the emotional face (valid trial, 60%), or on the other side (invalid trial, 40%).

Figure 27 illustrated the experimental design: Each trial started with a fixation cross measuring 2 x 2 cm in the centre of the screen for 200ms followed by an empty delay of 200ms and replaced by the display of the pair of faces. Emotional face was presented half on the right and half on the left visual field for 200ms. Between 200 and 600 ms after the disappearance of the cue, the probe was presented for 200ms, which could either replace the neutral face (valid trial, 60%), either the emotional one (invalid trial, 40%). A black screen was then displayed as an inter-trials interval, lasting for 1000ms. Six blocks were created which contained each 80 trials and the six blocks were repeated twice. The entire experiment counted 960 trials (576 valid and 384 invalid trials ; 36 stimuli for each 'valid' condition, and 24 for 'invalid' ones).

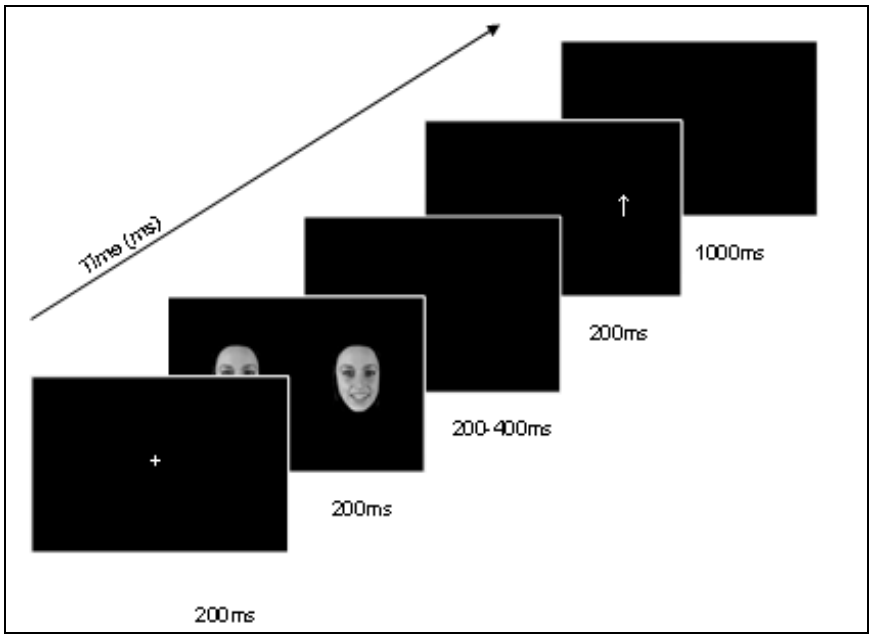


**Figure 27: Procedure used in the experiment, showing the temporal sequence of events within a trial.**

### 2.2.2. Procedure

The experiment took place between one and two weeks of the pre-selection of participants.

All stimuli were presented on a black background on a 17 in. computer Dell Inspiron with the sotware Eeprobe. During the ERP recordings, participants sat in a dark room on a chair placed at 30 cm from the screen with their head restrained in a chin rest. Before starting the task, practice trials, in which they could ask for additional information, were discounted to familiarize participants with the procedure. Participants were asked to press one of two response buttons to indicate the orientation of the arrow ("up" or "down"), and they were told that speed was important but not at the cost of accuracy.

Then, they were presented with the twelve blocks. They were tested individually in a single-session during approximately one hour.

### 2.2.3. Recording and data analyses

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 and were re-referenced by using a common average (Bertrand et al., 1985). The EEG was amplified by battery-operated A.N.T.® amplifiers with a gain of 30,000 and a band-pass of 0.01–100 Hz. The impedance of all electrodes was kept below 10 kΩ. The EEG was recorded continuously (sampling rate 500 Hz, A.N.T. Eeprobe software). Blinks and saccades were

controlled using horizontal and vertical electrooculogram (HEOG and VEOG). Trials containing EOG artefacts (mean of 15%) were eliminated off-line by computing an average artefact response based on a percentage of the maximum eye movement potential. The EOG response was 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 selectively average the epochs associated with different stimulus types. The data were averaged separately for each type of condition ("valid" and "invalid") and each type of emotion ("neutral", "happiness", "disgust", "fear" and "anger"), for cues and targets.

Different measures were recorded to assess subject's performances. Firstly, reaction times to each target presentation were automatically calculated by the software, and we computed averaged RT and percentage of errors. Errors could be an erroneous response, an absence of response within the given time, or a response occurring before target presentation or less than 200ms after its onset. For ERP, we reported latencies and amplitudes of target components.

Latencies and amplitude were calculated for every subject within latency windows on specific electrodes determined after the inspection of grand mean ERPs. These windows were kept constant for all subjects and conditions. Concerning cue stimuli, four ERP components were selected for the analysis after the review of the grand averages: (a) P100, the first major positive deflection, occurring on O1-O2-Oz occipital electrodes between 100 and 180

ms after cue presentation ; (b) the N100, its negative counterpart on frontal sites, measured on F3-F4 and Fz.; (c) the N170, a negative deflection occurring on posterior sites around 150-200ms after cue presentation, recorded on P7 and P8 electrodes; (d) the N300, a negative deflecting observable on frontal, central et parietal sites (F3-F4-Fz, C3-C4-Cz and P3-P4-Pz), between 250-350ms after stimulus occurrence.

Three ERP components were also selected for analysis of target stimuli processing: (a) the P100 and (b) the N100 (same characteristics as components described for face presentation) and c) the P300 component, peaking on parietal sites (P3-P4-Pz) around 350-450ms after target presentation.

Statistical analyses were computed using Statistical Package for Social Sciences, 14th version (SPSS 14.0). We conducted repeated-measures ANOVA (more details will be provided in 3.3.1 and 3.3.2 points) on dependant and independent variables. Greenhouse-Geiser epsilon correction was used to compensate for violation of sphericity when appropriate. Simple effects analyses of these factors were explored throughout; Bonferroni post-hoc tests and paired Student *t*-tests were used when appropriate. The sources of significant interactions were systematically examined through simple effects. The alpha level of significance was set at 0.05 throughout.

Analyses were conducted by integrating all explored factors: so Group, Validity (for target exclusively), Type of face pairs, Site of recording (when a wave was recorded on different brain areas, as it was the case of N300), Visual Field (emotional stimulus presented on the left or the right hemifield), and Electrode position (right, left or midline position). However, this report

focalized on the presentation of main effects and interactional effects implying emotions or group. A full summary of the effects is however available upon request.

## *3.* Results

### 3.1. Participants characteristics

Group did not differ in term of age ($t(24)=1.571$, N.S.) or depression level ($t(24)=1.565$, N.S.). The high social anxiety group scored higher than the low social anxiety group on measurements of social anxiety ($t(24)=14.302$, $p<.001$) but not on state ($t(24)=.953$, N.S.) or trait anxiety ($t(24)=-1.486$, N.S.). In conclusion, our groups only differed on the base of the presence or absence of social anxiety.

### 3.2. Behavioural data

We calculated the mean RT and the percentage of correct responses and misses during the ERP recording. Figure 28 illustrates behavioural effects, and Table 14 presents reaction times and percentages of correct responses by condition and by group, including means for the different conditions. Percentage of correct responses varied from 93 to 98%, revealing a ceiling effect. As a consequence, only reaction time will be analyzed.

The 5 (Type of face pairs) x 2 (validity) x 2 (groups) ANOVA revealed a main effects of Validity ($F(1,24)=12.355$, $p=.002$), with quicker responses for invalid trials (541 vs 545ms) and an interaction between Validity and Emotion ($F(3,72)=11.505$, $p<.001$) indicated a differential influence of emotion in valid and invalid trials. To explain this interaction, separate ANOVA comparing emotions were conducted in valid and invalid condition. Reaction time was more widely modulated by emotion in invalid ($F(3,75)=7.934$, $p<.001$) than in valid ($F(3,75)=3.907$, $p=.02$) condition.

**Table 14: Mean response times (RT, in ms) and percentage accuracy (RC, in %) for target detection in each condition for Healthy Participants and High Social Anxiety Group (Standard deviations are presented between brackets).**

| | | Anger | | Disgust | | Happiness | | Fear | |
|---|---|---|---|---|---|---|---|---|---|
| | | **RT** | **CR** | **RT** | **CR** | **RT** | **CR** | **RT** | **CR** |
| **Control Group** | **Valid Trial** | 535 (70.9) | 94,5 (4,1) | 538 (71.1) | 94,9 (3,1) | 544 (66.2) | 93,8 (2,9) | 545 (74.7) | 94,2 (3,2) |
| | **Invalid Trials** | 537 (72.5) | 93.8 (4,0) | 540 (65.9) | 94,2 (3,4) | 529 (69.9) | 95,1 (4,2) | 537 (76.5) | 93,9 (3,7) |
| **Social Anxious** | **Valid Trial** | 548 (68.8) | 96,2 (2,5) | 543 (68.7) | 95,9 (3,3) | 555 (74.1) | 94,9 (3,2) | 550 (80.2) | 95,7 (2,5) |
| | **Invalid Trials** | 552 (65.4) | 95,9 (3,3) | 546 (73.2) | 96,1 (2,9) | 533 (65.7) | 98,1 (1,7) | 547 (78.3) | 95,9 (3,5) |
| **Mean** | **Valid Trial** | 542 (68.8) | 95,3 (3,4) | 540 (68.5) | 95,4 (3,1) | 550 (69.1) | 94,4 (3,1) | 548 (76.0) | 94,9 (2,9) |
| | **Invalid Trials** | 545 (68.1) | 94,8 (3,7) | 543 (68.3) | 95,1 (3,3) | 531 (66.5) | 96,6 (3,5) | 542 (76.0) | 94,9 (3,7) |

More precisely, probes following neutral-anger and neutral-disgust pairs were faster detected if they followed the emotional faces, while the detection of probes succeeding to neutral face was facilitated in the case of neutral-happy and neutral-fear pairs (see Figure 28).

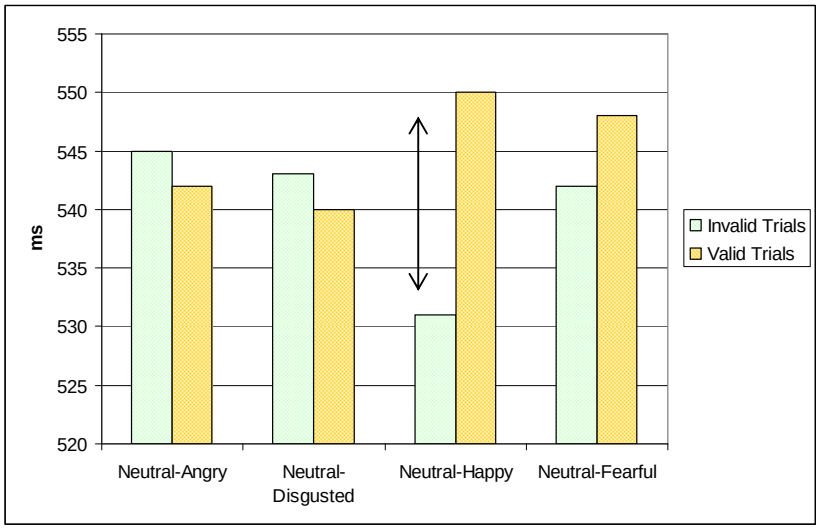


**Figure 28: Interaction effect between conditions and trial types.**

Group did not significantly affect response latencies ($F(1,24)=.216$, N.S.), but post-hoc comparisons were nevertheless conducted inside each groups since previous studies have demonstrated within-subjects bias in absence of between-subjects bias (see Bar-Haim et al., 2007; Mueller et al., 2008 for a theoretical rationale). The analyses revealed significantly longer latencies for probes invalidly-cued by pairs integrating anger as compared to disgust ($p=.015$) or happiness ($p=.045$) in SAP, while no emotional difference was reported by HCP.

### 3.3. ERP waveforms locked on the onset of the facial cues.

One of the main aims of the study was to compare the visual processing of face pairs, consequently we conducted analyses on N100, P100, N170 and N300 components directly related to processing of faces presented as cues.

#### 3.3.1. P100

The 2 (Disposition) x 4 (Type of face pairs) x 3 (electrode position) x 2 (groups) conducted on the N100 waves recorded on O1, O2 and Oz do not reveal any significant effects on latencies.

However, the same analyses on amplitudes disclosed a significant interaction between type of trials, electrodes and groups ($F(6,144)=2.712$, $p=.027$).

Firstly, this effect recovered the fact that HCP produced diminished response to Neutral-Anger, particularly as compared to Neutral-Disgust pairs ($p=.045$), while SAP did not elicited different amplitudes in response to emotional faces involved in the pairs.

Secondly, SAP produced enhanced amplitudes as compared to HCP. Figure 29 represents this group influence on P100. That enhancement was particularly marked for Neutral-Angry pairs (without electrodes influence), but also present for Neutral-Disgust pairs (on all electrodes and particularly for O2), and Neutral-Happy (particularly on O2, but absent on O1). However, for Neutral-Fear pairs, SAP produced P100 identical to control on O1, diminished amplitude on Oz and enhanced amplitude on O2.

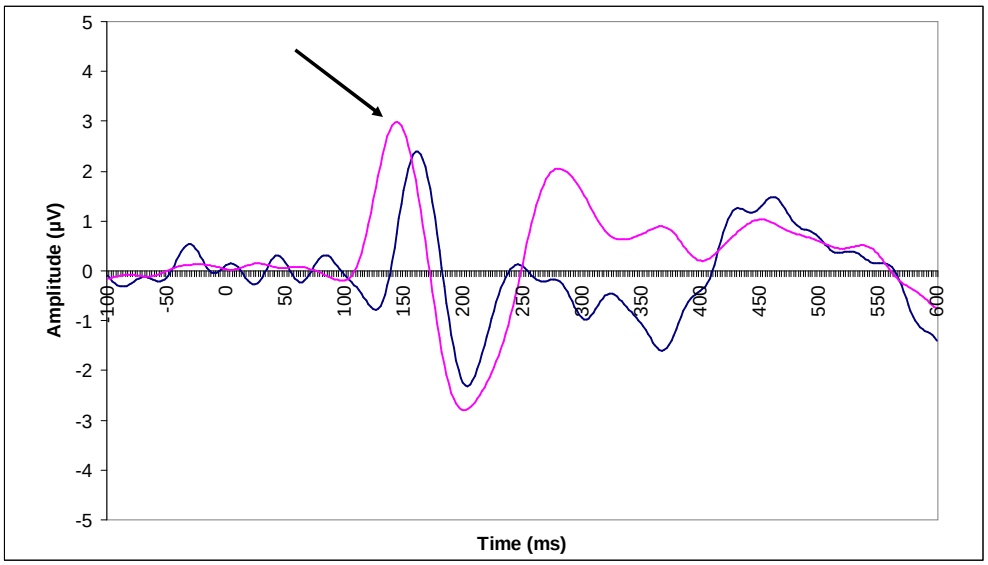


**Figure 29: Enhanced P100 in response to face pairs in SAP (pink line) as compared to HCP participants (blue line) on Oz electrode.**

### 3.3.2. N100

The 2 (Disposition) x 4 (Type of face pairs) x 3 (electrode position) x 2 (groups) conducted on the N100 waves recorded on F3, F4 and Fz displayed a main effect of type of trials on latencies amplitudes ($F(3,72)=3.103$, $p=.039$). The N100 was significantly decreased for neutral-fear pairs as compared to neutral-disgust ($p=.003$) or neutral-happy faces ($p=.034$), without differences

between the other types of pairs. Group did not modulated N100 parameters (latency: $F(1,24)=.243$, N.S.; amplitude : $F(1,24)=1.473$, N.S.) and did not interact with other factors.

### 3.3.3. N170

We conducted two separate 2 (Disposition) x 4 (Type of face pairs) x 2 (electrode position) x 2 (groups) ANOVA on latencies and amplitude of the N170 component, recorded on P7 and P8 electrodes. Latencies were not modulated by the chosen factors. However, a main effect of type of pairs appears on amplitude ($F(3,72)=3.103$, $p=.039$), and revealed an enhanced N170 for neutral-fear pairs as compared to neutral-disgust pairs ($p=.002$), without difference between the other conditions. Group effect did not reach significance ($F(1,24)=3.462$, $p=.075$, N.S.), but the tendencies of socially anxious participants to produce enhanced N170 (HCP: -4.42µV ; SAP: -6.14µV) was confirmed by significant interactions between Type of Trials x Electrodes x Groups ($F(3,72)=2.324$, $p=.013$), and between Disposition, Electrodes and Groups ($F(1,24)=5.514$, $p=.027$). The Figure 30 presents these interactional effects on mean amplitude for P7 and P8.

That first interaction indicated larger N170 on the right P8 electrode as compared to P7. However, that difference was quite weak on HCP but more important on SAP and specially for neutral-fear and neutral-anger pairs. Moreover, SAP evoked amplified N170 as compared to HCP, and particularly for Neutral-Disgust pairs on P8.

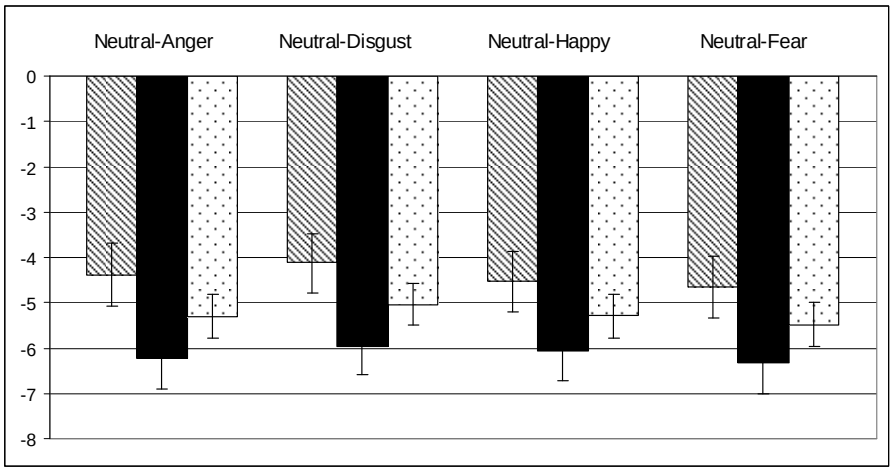


**Figure 30: Mean N170 amplitudes (bars represent standard errors) produced in response to face pairs in HCP (hatched bar) and SAP (black bar), together with response for both groups (dotted bar) (black bar), on averaged P7 and P8 electrodes.**

The second interactional effect reflected that the higher N170 on P8 was greater in SAP participants, specially when the emotional face was presented on the left visual field. Figure 31 illustrated amplitudes effects on P7 and P8 electrodes.

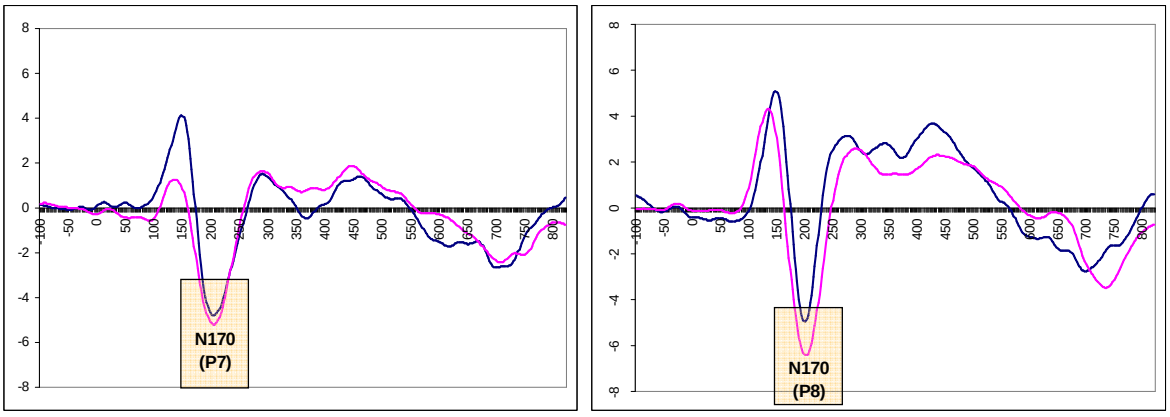


**Figure 31 : N170 in response to face pairs in SAP (pink line) and HCP (blue line) on P7 and P8 electrodes.**

### 3.3.4. N300

The 2 (Disposition) x 4 (type of face pairs) x 3 (electrode position) x 2 (groups) ANOVA conducted on the emotional N300, recorded on frontal electrodes[17], demonstrated a main effect of Field of presentation ($F(1,24)=9.438$, $p=.005$), with enhanced N300 when the emotional face took place on the Left visual field.

N300 amplitude was also influenced by Type of trials ($F(3,72)=4.179$, $p=.014$) indicating that N300 amplitude was reduced for Neutral-Happy pairs compared to Neutral-Angry ($p=.007$) or Neutral-Disgust ($p=.015$), without differences between emotional appraisal amplitude for pairs implying anger, fear or disgust. An interaction Type of trials x Group almost reached significance ($F(3,72)=2.697$, $p=.054$) and indicating that the emotional influence was higher on SAP. Particularly, SAP evoked greater N300 amplitude than HCP for pairs involving disgust (-2.28 vs -1.7 μV) and also anger (-2 vs -1.83 μV) but not fear (-1.78 vs -1.78 μV), and decreased amplitude for neutral-happy trials (-1.46 vs -1.61μV). Figure 32 represent these effects.

[17] A preliminary analysis demonstrated that N300 was enhanced on frontal electrodes ($F(2,48)=22.697$, $p<.001$), and justified our choice to focalize on frontal sites to perform our subsequent statistical analysis.

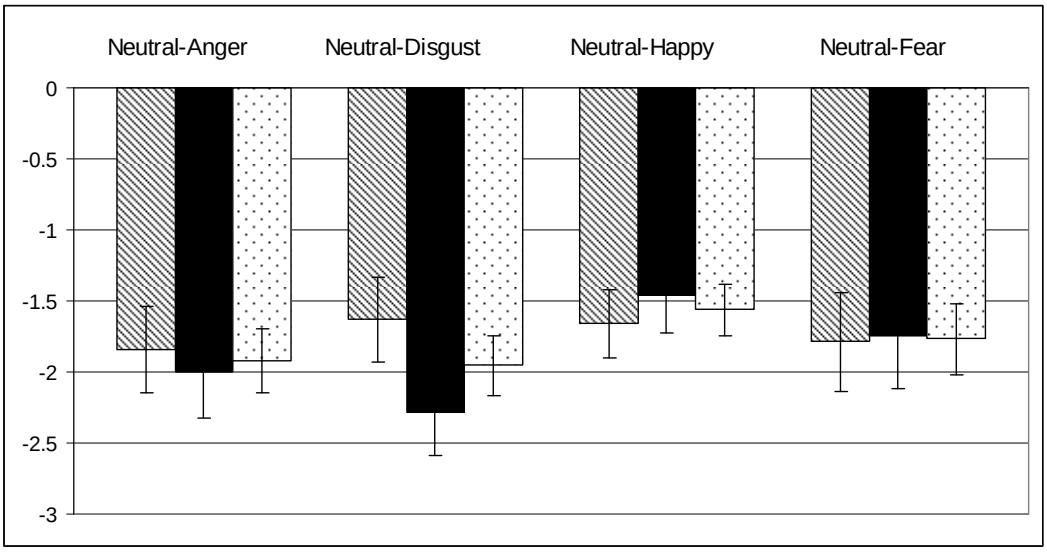


**Figure 32: Mean N300 amplitudes (bars represent standard errors) produced in response to face pairs in HCP (hatched bar) and SAP participants (black bar), together with response for both groups (dotted bar) (black bar), on averaged F3, F4 and Fz electrodes.**

### 3.4. ERP waveforms locked on the onset of the probe arrow.

The main effect reported for these was diminished amplitudes of N100 and P100 components for SAP participants, as illustrated by Figure 33.

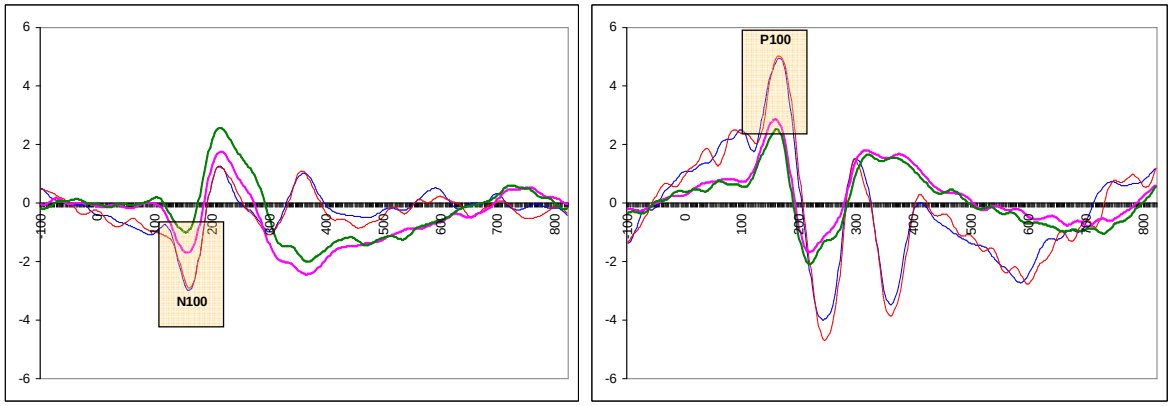


**Figure 33: Reduced P100/N100 complex in response to valid and invalid target in SAP (respectively Pink and Green thick lines) as compared to HCP (Blue and Red thin lines).**

### 3.4.1. N100

The 2 (validity) x 2 (Disposition) x 4 (type of face pairs) x 3 (electrode position) x 2 (groups) conducted on the N100 waves recorded on F3, F4 and Fz did not reveal main effect of validity, emotion or groups on latencies ($F(1,24)=.008$, N.S.; $F(3,72)=.317$, N.S.; $F(1,24)=.934$, N.S.) or amplitudes ($F(1,24)=.648$, N.S.; $F(3,72)=.498$, N.S.; $F(1,24)=.008$, N.S.).

However, Validity significantly interacted with Group on N100 amplitude ($F(1,24)=6.2$, $p=.02$) : As compared to HCP, SAP produced significantly decreased N100 amplitude, but this diminution was more pronounced in invalid condition.

Moreover, a significant interaction between Disposition, Type of trials and Group ($F(3,72)=3.096$, $p=.032$) indicated that the type of face pairs (emotional faces presented on the left or on the right) did not modulated N100 amplitude in HCP subjects, except for fear–neutral pairs, which evoked enhanced activity when the fearful face was presented on the left visual field. However, SAP evoked enhanced N100 for neutral-angry pairs when angry faces were presented on the right side and for disgust-neutral pairs when disgust was presented on the left (no difference for happy-neutral and fearful-neutral pairs).

### 3.4.2. P100

The 2 (validity) x 2 (Disposition) x 4 (type of face pairs) x 3 (electrode position) x 2 (groups) conducted on the N100 waves recorded on O1, O2 and Oz do not reveal any significant effects on latencies. However, the same

analyses on amplitudes disclosed a significant interaction of validity by type of trials ($F(3,72)=3.687$, $p=.031$). This interaction indicated that larger P100 were produced for valid target following neutral-anger pairs, while neutral-disgust cued-targets evoked larger neural responses in invalid condition.

The interaction between validity and group was tendencial ($F(1,24)=4.154$, $p=.053$) and reflected diminished amplitude of SAP participants (invalid probes: 3.6µV ; valid probes: 3.8µV) as compared to HCP (invalid trials: 4.7µV ; valid trials: 4.6µV), especially in invalid condition.

Additionally, an interaction between validity, disposition, electrodes and groups reached significance ($F(2,48)=3.539$, $p=.037$). That effect means that trials presented on the left visual field elicited enhanced amplitude on the right electrodes, and vice-versa. However, that enhancement was reduced in SAP as compared to HCP participants, especially in valid condition.

#### 3.4.3. P300

A 2 (validity) x 4 (Type of trials) x 2 (Disposition) x 3 (Electrodes) x 2 (groups) ANOVA was performed on amplitude and latencies of P300 component recorded on P3, Pz and P4 (see Figure 34 for a representation of P300 wave on Pz electrode).

Validity did not influence the parameters of P300, no more than Type of trials.

Electrodes position influenced the recording ($F(2,48)=6.112$, $p=.007$) : P300 appeared as decreased on the left (3.1µV) hemisphere as compared to the right (3.9µV, $p=.001$) or the midline position (3.8µV, $p=.001$).

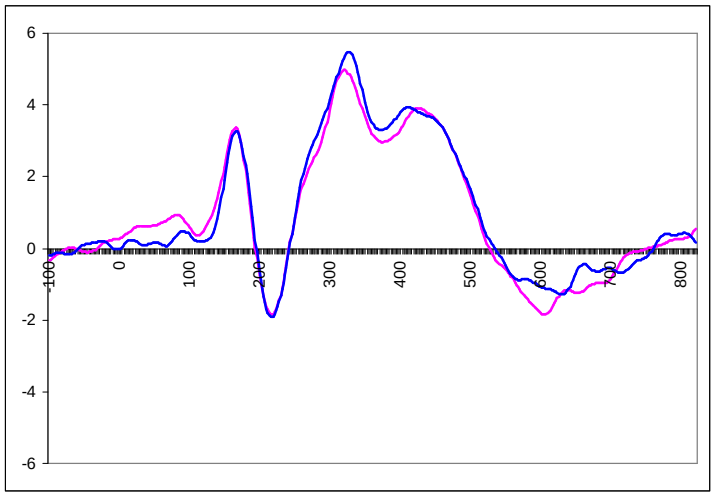


**Figure 34: P300 component recorded for all participants for valid (pink line) and invalid trials (blue line) on Pz electrodes.**

### 3.5. Correlation

To test whether P100/N100, N170 and N300 recorded in response to face on the one hand, and P1/N1 and P3b related to target processing on the other hand, are the successive steps of a continuum in cognitive processing, Pearson's correlations were performed between these components, for amplitude and latency. The results, shown in Table 15, demonstrated correlations between P100/N100 complex for cues and targets. Consequently, an earlier perceptive complex in response to cues was associated with a faster perceptive complex for targets. On the opposite, the speed of closure mechanisms indexed by the P300 components was negatively correlated with the speed of early visual processing of cues: the more cues were early processed, the more decisional processes related to these cues were delayed.

**Table 15 : Pearson's correlations and level of significance (*.05 ; ** .01; ***.001) between latencies and amplitudes (*italic*) of ERP waves produced in response to face-cues or probe-arrows.**

| | | ERP waves for Cues | | | | ERP waves for Targets | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **P100** | **N100** | **N170** | **N300** | **P100** | **N100** | **P300** | **TR** |
| **ERP waves for Cues** | **P100** | | .004 | -.248 | .034 | .699 *** | -.506 ** | -.504 ** | -.089 |
| | | | *-.17* | *.268* | *.067* | *.27* | *-.091* | *.162* | *-.068* |
| | **N100** | .004 | | .575 ** | -.305 | .096 | .650 *** | -.385 * | .136 |
| | | *-.17* | | *-.073* | *.034* | *-.188* | *.452* * | *-.039* | *-.264* |
| | **N170** | -.248 | .575 ** | | -.248 | .016 | .561 ** | -.052 | .012 |
| | | *.268* | *-.073* | | *.135* | *.063* | *.012* | *-.148* | *-.312* |
| | **N300** | .034 | -.305 | -.248 | | -.084 | -.178 | -.084 | -.109 |
| | | *.067* | *.034* | *.135* | | *.145* | *.041* | *-.148* | *-.122* |
| **ERP waves for Targets** | **P100** | .699 *** | .096 | .016 | -.084 | | -.357 | -.377 | .078 |
| | | *.27* | *-.188* | *.063* | *.145* | | *-.088* | *-.228* | *.209* |
| | **N100** | -.506 ** | .650 *** | .561** | -.178 | -.357 | | .084 | -.028 |
| | | *-.091* | *.452* * | *.012* | *.041* | *-.088* | | *-.622* *** | *-.029* |
| | **P300** | -.504 ** | -.385 * | -.052 | -.084 | -.377 | .084 | | -.32 |
| | | *.162* | *-.039* | *-.148* | *-.148* | *-.228* | *-.622* *** | | *-.236* |

Lastly, we checked whether psychological variables were associated with parameters of ERP components. There were no correlation with trait-anxiety level, but higher scores on the FNE scale were correlated with an enhanced N170 ($r$=-.521, $p$=.006), while state-anxiety scores were correlated with the speed of P100 wave ($r$=-.424, $p$=.031) and with the amplitude of N100 wave for face cues ($r$=.397, $p$=.044).

## 4. Discussion

The primary objective of this study was to explore the neurophysiological correlates of emotional processing in sub-clinical social anxiety. More specifically, we wanted to examine whether that disorder disrupts the processing of pairs of neutral and emotional faces, and whether modulations of attentional engagement and disengagement are observable when targets are cued by emotional faces. If socially anxious participants manifest hypervigilance to emotional faces in general, they should demonstrate enhanced P100/N100 complex for all types of face pairs, while a restricted enhancement to negative (angry, fearful and disgusted) faces would indicate a vigilance to negative evaluation. Moreover, an enhanced perceptive complex to probe replacing emotional faces would indicate a sustained hypervigilance, while diminished waves should reflect avoidance of the emotional cued location.

Firstly, SAP participants demonstrated increased P100 amplitudes in response to pairs of faces, confirming previous findings of enhanced perceptive response to faces in social anxiety (Kolassa et al., 2007; Kolassa & Miltner, 2006; Mueller et al., 2008). This enlargement was particularly marked for anger-neutral pairs, which evoked the lowest amplitudes among HCP. Moreover, increased P100 amplitude was also observed for disgust-neutral, neutral-happy, and fear-neutral pairs. In the latter case, however, increased amplitude was limited to the right hemisphere, which has been described as particularly involved in negative emotional processing (Adolphs et al., 2001),

and in the visual processing of emotional faces in anxiety (Fox, 2002; Mogg & Bradley, 2002).

Secondly, the N170 also reflected a tendency of SAP to produce increased amplitudes. Overall, N170 appeared as wider in the right hemisphere, for emotional face presented as in the left as in the right of the pair. In addition, SAP' tendency to produce increased N170 amplitudes was more marked in the right hemisphere than in the left hemisphere. Hence, this result confirms the implication of the right hemisphere in emotional processing, particularly in anxious individuals (Adolphs et al., 2001; Fox, 2002; Mogg & Bradley, 2002). In particular, the amplified processing of SAP was higher for Neutral-Fear and Neutral-Anger pairs. In addition, the amplitude difference between control and anxiety was clearer for Neutral-Disgust pairs: HCP produced decreased amplitudes for these stimuli when HAS did not. Finally, the production of an enhanced N170 was correlated with the report of a higher score of social anxiety at the FNE inventory (Watson & Friend, 1969), which evaluates cognitive features of this disorder, confirming previous results (Kolassa & Miltner, 2006) .

The N300 wave, known to reflect the emotional evaluation of a visual stimulus (Carretié & Iglesias, 1995; Carretié et al., 1997b), was modulated by anxiety: SAP showed a enhanced N300 wave for pairs of faces involving anger and disgust. In contrast, the amplitude produced by these subjects did not differ from those of HCP for pairs involving fear, and even appeared to drop in response to stimuli involving happiness. These data are in line with those

indicating a particular status of emotion of anger and disgust in social anxiety, as suggested these last years (Amir et al., 2005; Montagne et al., 2006; Rossignol et al., 2007). They also support the theory of a specific bias for emotion in relation to the concerns of anxious people (Blair et al., 2008; Stein et al., 2002). Thus, social anxiety involves a particular concern to emotional expressions depicting an interpersonal evaluation (Marcin & Nemeroff, 2003; Rapee & Heimberg, 1997). Anger is a direct threat and its relevance in the study of social anxiety has been widely recognized (see for instance Bar-Haim et al., 2007). In contrast, disgust did not arouse the interest of the scientific community until recently (see for instance Phillips et al., 1998b). Yet the emergence of a disgusted expression on the face of a speaker during a social interaction, without any food or taste context, certainly reflects a very negative evaluation (particularly in terms of judgment of physical appearance, odor, seduction potential) and may give rise to high trouble in patients suffering from social anxiety (Schofield et al., 2007).

Moreover, in general, an N300 enhanced was recorded for these Neutral-Angry or Neutral-Disgust pairs, particularly comparing to stimuli involving happiness. These results are in line with those involving the N300 in the appraisal of emotional arousal, which would be particularly high for anger (Schutter et al., 2004).

To sum up these results on the initial perceptual processing of faces, it appears that subjects with high social anxiety operate a modulated emotional processing: Their initial perceptive responses are enhanced, and this effect has

been related to increased activity in the extrastriate visual cortex in a recent study using a similar paradigm (Mueller et al., 2008). Secondly, they produce a deeper encoding of structural characteristics and emotional charge of faces, as already demonstrated in a previous study (Rossignol, Campanella, Falbo & Philippot, Submitted-b).

In a second step, we investigated how these modulations could act on the processing of targets appearing in a brief interval after faces pairs. Socially anxious participants evoked a decreased P100/N100 complex as compared to HCP participants, indexing a diminution of attentional orientation towards these targets. Moreover, the P100 wave appeared particularly reduced in the case of non-valid target, succeeding to a neutral face. Its negative counterpart, the N100, revealed smaller amplitudes in invalid condition, when the arrow appeared in the location previously occupied by a neutral face, than in valid condition, when the arrow followed the emotional face. In their study, Mueller et al. (2008) reported reduced P100 amplitude for targets following emotional faces, and proposed two alternative explanations. First, these amplitudes could reflect a sustained vigilance to emotional faces, which reduces the available resources for further processing. Secondly, these authors postulated that this decrease could reflect increased attention to the least threatening and the most ambiguous face of the pair, which retains attention and evokes a more salient process to its location. In our study, the amplitudes of P100 and N100 waves were particularly decreased for targets cued by neutral faces. As a result, it seems that in the sub-clinical anxiety, the emotional face captures the

attention and evokes an increased process of its location as compared to a neutral face.

These observations outline the role played by engagement and disengagement processes. Indeed, if attention is focused on the emotional face, a target which appears in that location occurs where visual attention is already engaged, involving a process of facilitated orientation. On the contrary, if attention is fixed on a face and the target occurs on the other side of the screen, participants have to disengage their attention and shift to the other side, implying attentional disengagement. Consequently, the decreased amplitudes of N100/P100 complex for invalid targets suggest disengagement difficulties of subjects suffering from sub-clinical social anxiety and confirm previous conclusions. (Fox et al., 2002; Koster et al., 2004). Nevertheless, despite more marked amplitude reduction on invalid condition, the target-related attentional processes were significantly decreased in SAP as compared to HCP, and the absence of specific emotional modulation might index the sustained vigilance to faces and the global difficulty to disengage from them, as already postulated in other studies (Rossignol et al., 2007).

The P300 wave was not affected by social anxiety. Previous studies have already shown a modulation of P300 by trait anxiety (Rossignol et al., 2008; Rossignol et al., 2005), but not by social anxiety (Kolassa et al., 2007; Rossignol et al., Submitted-b; Rossignol, Philippot, Bissot & Campanella, En Preparation). Therefore, this result supports the hypothesis of early

modulations associated with social anxiety, but without influence on later more elaborative stages of the cognitive processing.

Finally, sub-clinical social anxiety does not mainly affect the pattern of behavioral response, but SAP produced longer response for probes succeeding to a neutral face presented together with an angry one, which may indicate difficulty to disengage from the localization of that threatening stimuli. On the opposite, they were not faster to detect probe succeeding to angry facial stimuli. Social phobia has been reported to gave rise to faster behavioral responses for targets replacing angry faces in an ERP study using similar kind of paradigm (Mueller et al., 2008), but that difference could not be attributed to sub-clinical level of participants recruited in this study since a large amount of studies evidenced emotional biases towards threat in sub-clinical anxious population (Garner et al., 2006; Mogg & Bradley, 2002). In our study, SAP demonstrated an enhanced processing of faces pairs involving anger, from earlier perceptive to emotional appraisal stages, including face decoding step. However, no difference was observable at the level of subsequent probes processing, which appeared as decreased for all type of cued-probes, as if the difficulty in disengaging attention was proportional to the increased orienting and annihilate any effect at this level.

These observations stress the interest to consider performance in a cognitive model of engagement / disengagement, and not only of vigilance / avoidance. They also demonstrate the usefulness of an approach integrating electrophysiological and behavioral observations in the field of cognitive

psychopathology, as is the case in the healthy population (see for instance Vuilleumier, 2005). In addition, these results bare clinical significance, because they confirm the implication of inhibition abilities of people with social anxiety. Indeed, if SAP are likely to show a greater orientation toward threat, they also cumulate a deficit of the ability to disengage their attention from these objects, a process involving the inhibition (Fox et al., 2005). Further studies recruiting more participants should replicate these preliminary observations.

In conclusion, this study aimed at investigating the effects of social anxiety on facial expression processing and their influence on subsequent targets detection. To our knowledge, this study is the first to explore the electrophysiological correlates of performance of participants suffering sub-clinical social anxiety in a classic dot-probe paradigm. In the absence of major behavioral change, the inspection of electrophysiological correlates of the task suggests that sub-clinical social anxiety lead to an enhanced perceptive processing of neutral-emotion faces pairs, which affects the subsequent processing in the sense of vigilance to the location of faces and difficulties to disengage from them.

# Chapitre 8 :

# Implication spécifique

# des processus de désengagement

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Electrophysiological correlates of vigilance towards faces and disengagement difficulties in social anxiety.

En préparation.

## Abstract

The dot-probe paradigm has been extensively used to investigate attentional biases towards threat in anxious states. However, despite a large amount of behavioral data, the cognitive processes underlying the generation of this bias remain uncertain. Engagement and disengagement processes have been implicated in emotional processing, but the differential influence of these mechanisms remains controversial. This study explored the role of attentional disengagement in emotional processing and their temporal course, through electrophysiological activity. High (SAP) and low socially anxious individuals (HCP) performed a modified version of the emotional cued-target paradigm, in which an unique cue consisting in a neutral or an emotional face (with disgusted, happy, fearful or angry expression) preceded a small arrow that participants had to discriminate. ERP components associated to face-cues and targets processing were analyzed. At a behavioral level, SAP did not show benefit from cueing. Analyzes of ERP components locked on faces onset showed that social anxiety was associated with enhanced perceptive P100 component, but also with diminished N200, associated with top-down attentional control, and increased P200, reflecting mobilization of attentional resources. Moreover, SAP displayed enhanced P100 component in response to targets, as if the presentation of face cues had increased their perceptual responsiveness. The absence of modulation by emotional expression suggests that social anxiety is associated with an enhanced attentional anchorage on face stimuli, coupled with an inability to inhibit their process leading to disrupted processing of subsequent targets.

## 1. Introduction

The existence of an "emotional attention" phenomenon has been widely demonstrated in recent literature (Vuilleumier, 2005). It appears that human beings preferentially orient their attention towards emotionally valence stimuli and prioritize emotional cues in their environment, with a particular interest for those evoking the presence of a threatening or fearful situation (for a review, see Debatisse et al., 2006).

Because of their particular relevance in everyday life and social interaction and their high visual representation, EFE elicited a particular interest. Electrophysiological correlates of EFE processing show very early modulations related to their emotional load, since 100 ms after their onset (Balconi & Pozzoli, 2003; Eimer & Holmes, 2002). For instance, the P100 wave, specifically devoted to basic visual perceptual processing (Allison, Puce, Spencer & McCarthy, 1999), is increased for fearful faces (Batty & Taylor, 2003; Streit et al., 1999). Emotional modulations also affect the N170 (Ashley et al., 2004; Batty & Taylor, 2003; Campanella et al., 2002b), the P300 (Campanella et al., 2002a; Krolak-Salmon et al., 2001), as well as the N300 components. This last one has been described to be larger for emotional stimuli than for neutral ones (Carretie & Iglesias, 1995) independently of the physical properties of the stimuli.

Consequently, the specific processing of emotional stimuli has been largely documented in healthy subjects and it has been proposed that stimuli-valence influences early ERP components (100-200ms) while stimuli-arousal modulates later processes (200-1000ms) (Olofsson et al., 2008). Such

emotional modulations might be specially enhanced in anxiety and more specifically in social anxiety, since that pathology has been characterized by abnormal processing of social information, particularly conveyed by faces (Rapee & Heimberg, 1997). Indeed, a large amount of behavioural studies has outlined the enhanced detection of threat-cues in social anxiety. Anxious people show increased orienting and sustained attention towards threat stimuli, in visual search (Gilboa-Schechtman et al., 2005) as well as in target detection paradigms (Mogg & Bradley, 2002; Mogg et al., 2004). However, it is surprising to realize that only few studies have investigated face processing in social anxiety through electrophysiology while, thanks to its optimal resolution, ERP allow the identification of the electrophysiological components representing the onset of a dysfunction, and then to infer the impaired cognitive stages (Rugg & Coles, 1995).

Studies have reported modulation of early perceptive processing stages in social anxiety (Kolassa & Miltner, 2006), and modulation of attentional resources allocation towards anger and disgust faces (Rossignol et al., 2007). Moreover, enhanced N170 (Kolassa & Miltner, 2006) and P300 (Moser et al., 2008; Sewell et al., 2008) waves have been observed when social phobic patients processed angry faces, confirming the specific status of that emotion in social anxiety. As a consequence, social anxiety seems to globally enhanced perceptive processing of facial stimuli, and to selectively enhance processes related to structural analyses and response preparation when faces depicted anger.

However, these studies used other paradigms than the task most commonly used to evidence attentional biases in anxiety: the dot-probe paradigm. Stemming from Posner's works on attention networks (Posner & Petersen, 1990), that task has been adapted to investigate attentional deployment toward emotional material (see for instance MacLeod et al., 1986) : Pairs of stimuli (usually a neutral stimulus and an emotional ones) briefly appear at two different spatial locations on a screen. After their offset, a dot probe appears at one of these two locations. The allocation of attention is measured by the time needed to respond to the probe, with the hypothesis of a quicker detection of probe located where the attention was already directed. Attention is expected to be driven towards the emotional cue, and the target following it should consequently been faster detected.

Several studies have reported that anxious individuals demonstrate an enhanced attention to the location of threatening faces in dot-probe tasks, leading to increased detection of targets that appear in these locations (Bradley et al., 1998; Fox, 2002; MacLeod et al., 1986; Telzer et al., 2008). These results have been initially attributed to an enhanced orienting towards threat. However, distinct components of attentional system have been proposed by Posner and Petersen (1990), and notably *orienting toward stimuli* and *disengaging from stimuli*. It means that, in the case of incongruent presentation, subjects have to disengage from location of the cue, moving to the location of the target, and engaging this new location. Consequently, the facilitated responses to valid probes succeeding to threat cues may arise from difficulty to disengage from the threat location, rather than vigilance to threat

(Koster et al., 2004). Indeed, Fox et al. (2001) highlighted the necessity to evaluate the distinct function of emotions on drawing and holding attention, and suggested to use a single cue to observe disengaging abilities. Comparisons between responses following neutral stimuli have also been proposed to measure difficulties to disengage from threat (slower response to dots replacing threat stimuli in the other location) and fast orienting towards threat (faster responses to target replacing the location of the threat stimuli) (Koster et al., 2004). Anxious people seem particularly sensitive to attentional disengaging, and a delay in disengaging from threat in high-state anxiety was reported by Fox et al (2001) who used angry, happy and neutral faces as cues. In the same way, Yiend and Mathews (2001) used neutral or emotional pictures as cues for neutral target, and observed that high-anxious individuals had difficulties in disengaging their attention from threat pictures, but they did not differ to low anxious subjects in orientation towards threatening stimuli. In conclusion, uncertainty remains about the specific attentional processes involved in the task (Mogg et al., 2008).

Due to their excellent temporal resolution, ERPs allow exploring perceptive and attentional processes, and may help to disentangle attentional mechanisms involved in the production of emotional biases in the dot-probe task. For instance, electrophysiological correlates of that task evidenced a facilitated sensorial processing of stimuli succeeding to fear faces (Pourtois et al., 2004), angry faces (Santesso et al., 2008), as well as faces of babies (Brosch et al., 2008). These results indicate an increase of the visual processing by spatial attention, confirming the hypothesis of an attentional attraction for

biologically prepared stimuli. However, if some data have been published concerning healthy participants, this field of study is only emerging in psychopathological populations. A first study of Bar-Haim et al. (2005) used an attention-shifting paradigm with a central face cue and demonstrated that high trait-anxious participants are slower to detect targets succeeding to emotional cues than low-anxious participants. Moreover, high trait-anxiety was associated to a faster N1/P1 complex in response to cues, and to higher amplitudes of P2 component for angry faces specifically. These results were interpreted as indexing a greater mobilization of attentional resources in high-anxious participants, interfering with identification of subsequent objects. Very recently, a study investigated the neural bases of performances of social phobic patients in a dot-probe paradigm coupled with a go/no go task (Mueller et al., 2008). Authors mainly reported enhanced P100 amplitudes and fusiform gyrus activation to angry-neutral vs. happy-neutral face pairs in social phobia, and decreased P100 amplitude to probes succeeding to emotional as compared to neutral faces. These results were interpreted within the framework of vigilance/avoidance theory, as the sign of an increased early vigilance to faces, followed by a reduced visual processing of emotionally salient locations at later stages of cognitive processing. These data consistently outline difficulties to process targets following emotions cues but, despite these very interesting clues, they did not investigate how disengagement may interfere with initial engagement process.

As a consequence, the present study aimed at examining how the mechanisms of attentional engaging and disengaging are involved in social

anxiety. We hypothesized that difficulty to disengage from emotional stimuli would emerge in invalid condition. In order to decide between slower disengaging or faster engaging, we adapted a paradigm developed by Fox et al. (2001): a single lateralized cue consisting of an emotional or a neutral face was presented on the left or the right hemi-field. Then, an arrow appeared at the site previously occupied by the face, or at the empty location, and the subject was to discriminate the orientation of the target as quickly and accurately as possible (for a discussion of difference between detection and discrimination tasks, see Salemink et al., 2007b; Van der Lubbe, Vogel & Postma, 2005).

The paradigm was designed to study the process of attentional disengagement. Indeed, when two faces are presented simultaneously, the participants have the opportunity to direct their attention successively to one or the other face, and the role of facilitated engagement is intricate with the effect of a complicated disengagement (Fox, 2004; Fox et al., 2001). Our paradigm allowed solving this problem by comparing the valid and invalid conditions. As the cue consisted in a single face, we postulated that participants would focus their attention towards this cue. Therefore, acceleration in valid condition would index a facilitated engagement, while a delay in invalid condition would implicate difficulties in disengagement process.

To explore the influence of emotional load, we integrated four types of emotional faces as cues: angry, fearful, disgusted and happy faces, contrasted with neutral faces. The choice of these specific emotions resulted from

evidenced of an impaired processing of fear and anger in anxiety (Mogg et al., 2004; Monk, Telzer, Mogg, Bradley, Mai, Louro, Chen, McClure-Tone, Ernst & Pine, 2008), and with results suggesting a particular role of disgust in anxious states and particularly in social anxiety (Amir et al., 2005; Montagne et al., 2006; Rossignol et al., 2007).

We hypothesized that facilitated engaging would be observable through enhanced performance in valid trials while difficulty to disengage would affect subsequent target processing of invalid trials succeeding to negative emotional cues. An increased P100 for validly-cued target would imply enhanced orienting, while decreased P100 for invalid trials should outline diminished attentional resources and in consequence disrupted disengagement. Lastly, on the base of results described by Pourtois et al. (2004) and Santesso et al. (2008), we hypothesized that the modulation of visual area activity indexed by increased early components in response to targets following negative cues would be enhanced in high social anxious participants.

## 2. Materials and methods

### 2.1. Participants

Thirty participants were pre-selected based on their score on the Spielberger State and Trait Anxiety Inventory (STAI, Spielberger et al., 1983) and on the Fear of Negative Evaluation questionnaire (FNE, Watson and Friend, 1969) from a sample of students from the University of Louvain. Two participants were excluded because of artifacts during ERP recording, so that twenty-eight participants remained in the sample. All participants were right-handed, between the ages of 18 and 24 years, with normal/corrected vision, and without neurological disease or depression.

Since our aim was to contrast groups exclusively on social anxiety, we selected participants with low score to Beck Inventory (Beck & Beamesdefer, 1974) and with normal or low scores on STAI, and we used the typical cut-off score of 19 for the FNE scale (see Douilliez and Philippot, 2003; Philippot and Douilliez, 2005). On these bases, we created a group of healthy control participants (HCP), and a group social anxious participants (SAP). Group characteristics are reported in Table 16.

**Table 16: Mean scores (and standard deviations) for questionnaire measures of State-Anxiety (STAIA), Trait-Anxiety (STAIB), Social Anxiety (FNE) and Depression (Beck).**

| | Age | Ratio male/female | STAI-A | STAI-B | FNE | Beck |
|---|---|---|---|---|---|---|
| **Social Anxious Participants (N=14)** | 19.6 (1.4) | 3/11 | 50.6 (5.2) | 48.2 (5.2) | 22.7 (3.3) | 4.7 (3.2) |
| **Healthy Participants (N=14)** | 21.6 (3.2) | 5/9 | 43.8 (4.2) | 41.2 (5.6) | 6.1 (3.9) | 2.5 (2.7) |

## 2.2. Material and procedure

### 2.2.1. Materials

The stimuli set comprised 30 grey pictures of six different individuals (3 males and 3 females) each posing neutrality, anger, disgust, happiness and fear, taken from the database elaborated by Beaupre and Hess (2006). After being trimmed to exclude non-facial contours and hair, each facial stimulus was enclosed within a rectangular frame measuring 4x6cm, subtending 4.7° x 8.5°, and were presented either on the left, either on the right visual field.

The target stimulus was a white arrow pointing up or down, sizing 2cm (visual angle: 2.86°) and presented against a black background. The target was always presented unilaterally, on either the left or the right visual field (the type of probe, up or down, and the location of the probe, left or right, were counterbalanced through the task), at the location of the emotional face (valid trial, 57%), or on the other side (invalid trial, 43%). The entire experiment counted 480 valid and 360 non-valid trials.

All stimuli were presented on a black background on a 17 in. computer Dell Inspiron with the sotware Eeprobe. Figure 35 illustrates the experimental design: Each trial started with a fixation cross measuring 2 x 2 cm in the centre of the screen for 200ms followed by an empty delay of 200ms and replaced by the display of the face-cue. Face was presented on the right or on the left visual field for 200ms, with an equal repartition on the left and the right side throughout the experiment. Between 200 and 600 ms after the disappearance of the cue, the probe was presented for 200ms, which could either replace the faces, either appeared on the previously empty field. A black screen was then displayed as an inter-trials interval, lasting for 1000 ms. Six blocks were created which contained each 76 trials.

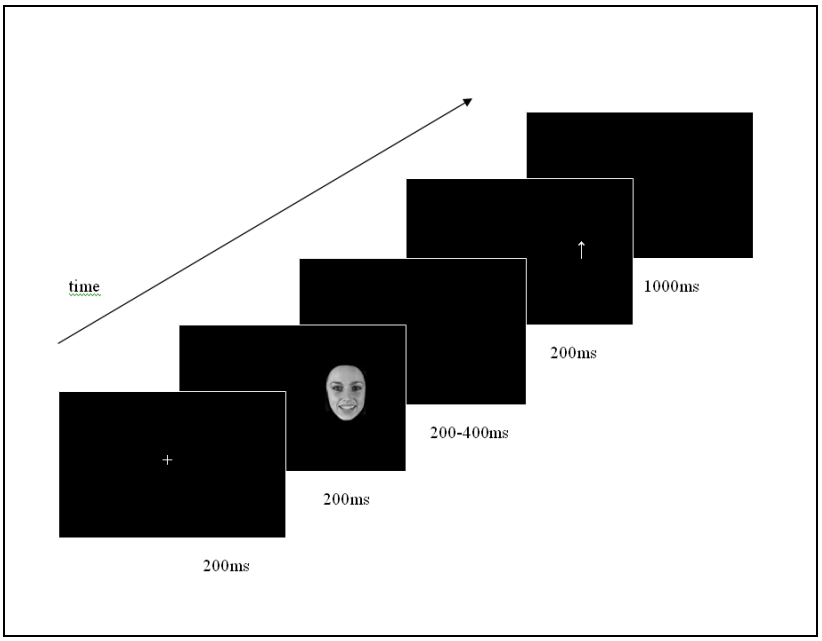


**Figure 35 : Procedure used in the experiment, showing the temporal sequence of events within a trial.**

Participants were asked to press one of two response buttons to indicate the orientation of the arrow ("up" or "down"), and they were told that speed was important but not at the cost of accuracy.

### 2.2.2. Procedure

The experiment took place between one and two weeks of the pre-selection of participants. During the ERP recordings, participants sat in a dark room on a chair placed at 30 cm from the screen with their head restrained in a chin rest. Before starting the task, practice trials familiarize participants with the procedure. Then, they were presented with the twelve blocks (6 blocks repeated twice) of xx trials. They were tested individually in a single-session during approximately one hour.

### 2.2.3. Recording and data analyses

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 and were re-referenced by using a common average (Bertrand et al., 1985). The EEG was amplified by battery-operated A.N.T.® amplifiers with a gain of 30,000 and a band-pass of 0.01–100 Hz. The impedance of all electrodes was kept below 10 kΩ. The EEG was recorded continuously (sampling rate 500 Hz, A.N.T. Eeprobe software). Blinks and saccades were controlled using horizontal and vertical electrooculogram (HEOG and VEOG). Trials containing EOG artefacts (mean of 15%) were eliminated off-line by computing an average artefact response based on a percentage of the maximum eye movement potential. The EOG response was 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 selectively average the epochs associated with different stimulus types. The data were averaged separately for each type of condition ("valid" and "invalid") and each type of emotion ("neutral", "happiness", "disgust", "fear" and "anger"), for cues and targets.

Different measures were recorded to assess subject's performances. Firstly, reaction times to each target presentation were automatically calculated by the software, and we computed percentage of errors and averaged RT for correct and erroneous responses. Errors could be an erroneous response, an absence of response within the given time, or a response occurring before target presentation or less than 200ms after its onset.

For ERP, we reported latencies and amplitudes of target components. Latencies and amplitude were calculated for every subject within latency windows on specific electrodes determined after the inspection of grand mean ERPs. These windows were kept constant for all subjects and conditions. Concerning cue stimuli, five ERP components were selected for the analysis after the review of the grand averages: (a) P100, the first major positive deflection, occurring on occipital electrode between 100 and 180 ms after cue presentation and measured on O1, O2 and Oz electrodes ; (b) the N100, its negative counterpart on frontal sites, measured on F3, F4 and Fz.; (c) the N170, a negative deflection occurring on occipito-temporal sites around 150-

200ms after cue presentation, measured on T5-T6-O1-O2 and Oz; (d) the P200, a positive deflection peaking at occipital sites around 200ms and (e) the N300, a negative deflecting observable on frontal, central et parietal sites (F3-F4-Fz, C3-C4-Cz and P3-P4-Pz), between 250-350ms after stimulus occurrence.

Three ERP components were also selected for analysis of target stimuli processing: (a) the P100 and (b) the N100 (same characteristics as components described for face presentation) and c) the P300 component, peaking on parietal-occipital sites (P3-P4-Pz and O1-O2-Oz) around 350-450ms after target presentation.

Statistical analyses were computed using Statistical Package for Social Sciences, 14th version (SPSS 14.0). We conducted repeated-measures ANOVA (more details will be provided in 3.3.1 and 3.3.2 points) on dependant and independent variables. Greenhouse-Geiser epsilon correction was used to compensate for violation of sphericity when appropriate. Simple effects analyses of these factors were explored throughout; Bonferroni post-hoc tests and paired Student *t*-tests were used when appropriate. The sources of significant interactions were systematically examined through simple effects. The alpha level of significance was set at 0.05 throughout.

Analyses were conducted by integrating all explored factors: Group, Validity, Emotion, Site of recording (when a wave was recorded on different brain areas), but also Visual Field (stimulus presented on the left or the right visual field), and electrode position (right, left or midline position).

## 3. Results

### 3.1. Participants' characteristics

Group did not differ in term of age ($t(26)=2.04$, N.S.) or depression level ($t(26)=2.021$, N.S.). The high social anxiety group scored higher than the low social anxiety group on measurements of social anxiety ($t(26)=12.027$, $p<.001$) but also on state ($t(26)=3.791$, $p=.001$) and trait anxiety ($t(26)=3.495$, $p=.002$). However, the state or trait anxiety score of SAP remains below the threshold defined by Spielberger et al. (1983) to discriminate an anxious state.

### 3.2. Behavioural data

We calculated the mean RT and the percentage of correct responses and misses during the ERP recording. Table 17 presents reaction times and percentages of correct responses by condition and by group, including means for the different conditions.

**Correct responses**: the 2 (validity condition) x 5 (emotion) x 2 (groups) ANOVA revealed a main effect of Validity ($F(1,26)=82.923$, $p<.001$) with better performance for validly-cued trials. Secondly, a main effect of Emotion ($F(4,104)=21.154$, $p<.001$) was moderated by an significant Validity x Emotion interaction ($F(4,104)=25.214$, $p<.001$). Indeed, the emotional effect was only apparent on Invalid Condition ($F(4,108)=7.882$, $p<.001$) and not in Valid one ($F(4,108)=.505$, N.S.). Anger conducted to the better performance in invalid condition (Difference between valid condition: -.37%), followed by

Fear (-1.8%), Happiness (-3.3%), and Neutrality (-5.9%), while Disgust led to the worse performance (-8.1%) (See Table 17).

**Response latencies**: The 2 (validity condition) x 5 (emotion) x 2 (groups) ANOVA revealed a main effect of Validity ($F(1,26)=12.080$, $p=.002$) : participants responded faster to validly-cued targets. A Validity x Emotion interaction ($F(4,104)=5.252$, $p=.001$) meant that emotion only acted on invalid condition ($F(4,108)=7.882$, $p<.001$) but not on valid condition ($F(4,108)=.732$, N.S.). This interaction was however responsible of a main effect of Emotion ($F(4,104)=3.762$, $p=.01$). The larger difference between valid and invalid condition was observed for disgusted face (difference: 31.8ms) as compared to anger (18.4 ms; $p=.003$), happiness (11.5 ms; $p=.001$), neutrality (20.9 ms; $p=.028$) or fear (17.7 ms; $p=.05$).

**Table 17 : Mean response times (RT, in ms) and percentage accuracy (RC, in %) for target detection in each condition for Healthy Participants and High Social Anxiety Group (Standard deviations are presented between brackets).**

| | | Anger | | Disgust | | Happiness | | Neutrality | | Fear | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **RT** | **CR** | **RT** | **CR** | **RT** | **CR** | **RT** | **CR** | **RT** | **CR** |
| **HCP** | **Valid Trial** | 541 (70.1) | 95.9 (4.1) | 536 (67.5) | 94.7 (3.7) | 543 (69.0) | 95.3 (4.6) | 542 (68.0) | 95.7 (4.3) | 537 (65.8) | 94.7 (3.7) |
| | **Invalid Trials** | 567 (74.2) | 93.8 (5.9) | 575 (84.6) | 87 (5.1) | 559 (77.5) | 92.7 (3.8) | 566 (82.3) | 88.7 (3.8) | 565 (80.9) | 93.0 (3.9) |
| **SAP** | **Valid Trial** | 558 (64.5) | 94.2 (5.7) | 555 (62.3) | 95.7 (5.7) | 556 (59.4) | 96.2 (3.9) | 555 (56.9) | 95.5 (5.2) | 558 (65.6) | 95.7 (5.7) |
| | **Invalid Trials** | 570 (66.2) | 94.7 (5.8) | 577 (61.7) | 86.3 (8.6) | 559 (59.6) | 91.5 (6.5) | 569 (59.6) | 90.5 (6.6) | 565 (60.5) | 93.2 (7.0) |
| **Mean** | **Valid Trial** | 550 (66.8) | 95.0 (5.0) | 546 (64.6) | 95.2 (4.8) | 550 (63.5) | 95.7 (4.8) | 549 (61.9) | 95.6 (4.7) | 548 (65.5) | 95.2 (4.8) |
| | **Invalid Trials** | 569 (69.1) | 94.3 (5.7) | 576 (72.6) | 86.6 (7.1) | 559 (67.8) | 92.1 (5.3) | 568 (70.4) | 89.6 (5.4) | 565 (70.0) | 93.1 (5.6) |

Group effect did not reach significance ($F(1,26)=1.175$, N.S.) but, as shown by Figure 36, the pattern of responses was different in HCP or SAP, and we decided to conducted separate analyses in groups (see Mueller et al., 2008 and Bar-Haim et al., 2007, for a theoretical justification). Indeed, control participants demonstrated a main effect of validity ($F(1,13)=10.168$, $p=.007$) and no emotional effect ($F(4,52)=.889$, N.S.), but the reverse pattern was observable in SAP (Validity effect : $F(1,13)=2.846$, N.S. ; Emotional Effect: $F(4,52)=3.328$, $p=.022$).

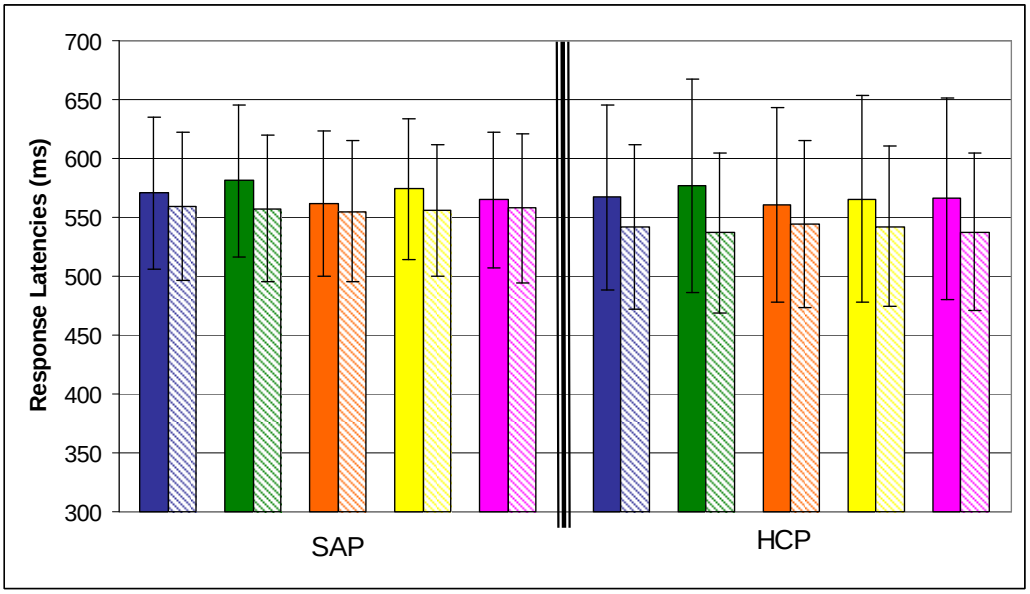


**Figure 36 : Mean response latencies (and Standard Deviations) for Valid (hatched bars) and Invalid trials (rounded bars) after cues displaying Anger (Blue); Disgust (Green); Happiness (Orange); Neutrality (Yellow) and Fear (Pink).**

Post-hoc analyses comparing valid and invalid cued trials confirmed that SAP did not benefit of cue validity, except for disgusted ($t(13)=2.494$, $p=.027$) and neutral faces ($t(13)=2.325$, $p=.037$) whereas control subjects always produced earlier responses for valid trials. So, anxious subjects were not faster

to detect valid trials than invalid ones, but their reaction times were modulated by the emotion conveyed by the faces. HCP did not show such emotional modulation.

### 3.3. ERP waveforms locked on the onset of the facial cues.

One of the main aims of the study was to compare the visual processing of emotional faces between SAP and HCP, consequently we conducted analyses on N100, P100, N170, P200 and N300 components directly related to processing of faces presented as cues (see Figure 37 for a pictorial representation).

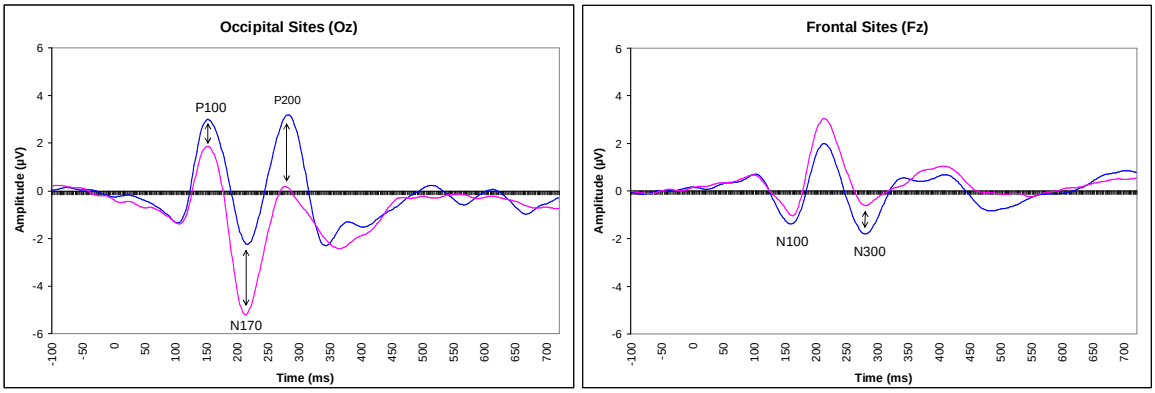


**Figure 37: Grand Average waveforms evoked by emotional faces on frontal and occipital electrodes (Fz and Oz in this case) for High Anxious (Blue Line) and Control Group (Pink Line).**

#### 3.3.1. N100

The 5 (emotion) x 2 (Visual Field) x 3 (Electrode Position) x 2 (Group) ANOVA performed on the latencies and amplitudes of the frontal N100 component, measured at three positions on F3, Fz and F4, revealed an interaction between Visual Field x Electrode Position ($F(2,52)=9.115$, $p=.002$) indicting delayed latencies on the opposed hemisphere. Emotion and Group

did not influence N100 latencies or amplitudes and did not interact other factor.

### 3.3.2. P100

The 5 (emotion) x 2 (Visual Field) x 3 (Electrode Position) x 2 (Group) ANOVA performed on the latencies of the lateral occipital P1 component, measured at O1, Oz and O2 in the occipital area, disclosed a main effect of Group ($F(1,26)=9.574$, $p=.005$), meaning that P100 was enhanced in SAP (4.306µV) as compared to HCP (2.511µV).

Visual Field interacted with Electrodes positions for P100 latency ($F(2,52)=28.06$, $p<.001$) and amplitude ($F(2,52)=6.347$, $p=.006$): lateralized stimuli evoked shorter latencies and decreased amplitude in the opposed hemisphere.

Emotion did not influence P100 amplitude or latencies, and did not interact with Group or Visual field.

### 3.3.3. N170

The 5 (emotion) x 2 (Visual Field) x2 (Electrode Position) x 2 (Group) ANOVA performed on the latencies and amplitudes of the N170 component on O1 and O2 in the occipital cortex and T5-T6 in the temporal cortex, disclosed a main effect of Site on latency ($F(1,26)=15.678$, $p<.001$) and amplitude ($F(1,26)=4.545$, $p=.043$) : N170 was earlier and enhanced on temporal (204ms ; -6.073µV) as compared to occipital sites (209ms ; -5.032µV). Significant interaction between Visual Field x Electrode Position on latency

($F(1,26)=71.384$, $p<.001$) and amplitude ($F(1,26)=4.914$, $p=.036$) meant that N170 appeared later and enhanced on opposed hemisphere.

Visual field significantly acted on N170 amplitude ($F(1,26)=11.51$, $p=.002$), with enhanced amplitude for faces presented in the right hemifield (-5.939 vs. -5.166μV).

Lastly, a significant Site x Group interaction ($F(1,26)=8.839$, $p=.006$) indicated similar amplitude on occipital and temporal sites in HCP (-6.798 vs. -6.387μV), while SAP produced diminished amplitude on occipital sites (-3.266 vs. -5.758μV).

Despite this tendencies to SAP to evoked reduced N170, Group effect did not reach significance ($F(1,26)=3.706$, $p=.065$, N.S.).

#### 3.3.4. P200

The 5 (emotion) x 2 (Visual Field) x 3 (Electrode Position) x 2 (Group) ANOVA performed on the latencies and amplitudes of the P200 component on O1 and O2 in the occipital cortex, revealed a main effect of Group ($F(1,26)=5.459$, $p=.027$) : as shown by Figure 37, SAP evoked a larger wave than HCP (3.71 vs. 1.4μV). Moreover, an significant interaction between Visual Field and Group ($F(1,26)=5.477$, $p=.027$) indicated that the P200 response of SAP was specially enhanced when stimuli were presented on the left visual field (3.03 vs. 4.398μV) while HCP did not evoked such difference (1.59 vs. 1.35μV).

Lately, a significant effect of Electrode Position ($F(2,52)=4.919$, $p=.023$) meant that P200 appeared enhanced on the right hemisphere (O2 : 2.9μV) as

compared to midline position (Oz : 2.3μV; $p$=.001) (no difference with O1: 2.6μV).

#### 3.3.5. N300

Lastly, a 5 (emotion) x2 (Visual Field) x 3 (Site of recording) x 3 (Electrode Position) x 2 (group) was conducted on N300 latency and amplitude, recorded in left, middle and right electrodes on frontal, central, and parietal cortex. A main effect of Group on latencies ($F$(1,26)=34.696, $p$<.001) and amplitudes ($F$(1,26)=5.552, $p$=.026) indicated delayed but enhanced N300 in SAP (315ms; -1.417μV) as compared to HCP (294ms; -.918μVs).

Moreover, a Group x Site interaction ($F$(2,52)=6.961, $p$=.003) demonstrated that the N300 latency was modulated by Site of recording with earlier N300 on frontal cortex as compared to other locations in SAP (central location:.316ms; frontal location:294ms; parietal location: 336ms) but not in HCP (central location:.293ms; frontal location:290ms; parietal location: 299ms). This interaction was however responsible of the observed main effect of Site ($F$(2,52)=16.407, $p$<.001) reporting earlier latencies on frontal sites. Emotion did not influence N300 parameters ($F$(4,104)=.652 for latency and 1.270 for amplitude, N.S.).

### 3.4. ERP waveforms locked on the onset of the probe arrow.

The main results obtained for ERP recorded in response to targets was a validity effect on P100 and N100 components, which were delayed for invalid trials (Validity effects are illustrated in Figure 38; see also Table 13).

**Table 18: Latencies and amplitudes of P100, N100 and P300 produced in response to cued-targets by SAP and HCP.**

| | | P100 | | N100 | | P300 | |
|---|---|---|---|---|---|---|---|
| | **Type of cue** | **HCP** | **SAP** | **HCP** | **SAP** | **HCP** | **SAP** |
| **Invalid** | **Anger** | 153<br>3.37 | 159<br>4.49 | 154<br>-1.75 | 154<br>-1.78 | 363<br>4.15 | 363<br>4.60 |
| | **Disgust** | 155<br>3.79 | 155<br>4.61 | 153<br>-1.54 | 152<br>-2.03 | 368<br>4.20 | 379<br>4.54 |
| | **Happiness** | 154<br>3.60 | 156<br>4.76 | 151<br>-1.49 | 154<br>-1.94 | 371<br>4.30 | 370<br>4.69 |
| | **Neutrality** | 156<br>3.55 | 157<br>4.45 | 154<br>-2.17 | 155<br>-1.83 | 365<br>4.42 | 366<br>4.61 |
| | **Fear** | 155<br>3.68 | 156<br>5.03 | 155<br>-1.56 | 154<br>-1.97 | 367<br>4.39 | 365<br>4.75 |
| **Valid** | **Anger** | 150<br>3.18 | 155<br>4.48 | 150<br>-1.23 | 150<br>-1.44 | 362<br>3.58 | 381<br>4.19 |
| | **Disgust** | 149<br>3.38 | 153<br>4.18 | 148<br>-1.34 | 149<br>-1.33 | 359<br>3.98 | 381<br>4.42 |
| | **Happiness** | 148<br>3.68 | 155<br>4.30 | 146<br>-1.22 | 149<br>-1.35 | 368<br>4.15 | 367<br>4.14 |
| | **Neutrality** | 151<br>3.04 | 154<br>4.61 | 145<br>-1.21 | 150<br>-1.59 | 363<br>4.04 | 373<br>4.79 |
| | **Fear** | 148<br>3.14 | 155<br>4.66 | 145<br>-1.14 | 145<br>-1.54 | 373<br>3.71 | 383<br>6.43 |

### 3.4.1. N100

The 2 (validity) x 5 (emotion) x 2 (group) performed on latencies and amplitude of the N100 component recorded on F3, F4 and Fz electrodes revealed a main effect of Validity on latencies ($F(1,25)=16.29$, $p<.001$) and amplitude ($F(1,25)=11.531$, $p=.002$), with delayed and enhanced N100 for invalid (153ms; -1.7µV) as compared to valid probes (147ms; -1.3µV).

An interaction between Visual Field and Electrodes position on latencies ($F(2,52)=22.98$, $p<.001$) meant that N100 appeared later in opposed hemisphere (presentation on the left : O1=.145ms, O2=160ms ; presentation of the right: O1=154ms, O2=144ms).

Main effects of Visual Field ($F(1,25)=5.2$, $p=.031$) and Electrodes Position ($F(2,50)=20.789$, $p<.001$) outlined enhanced amplitudes for probe

appearing in left hemifield (-1.711 vs -1.434µV) and increased N100 on right electrodes (-1.973µV) as compared to left (-1.34µV, $p<.001$) or midline electrodes (-1.26µV, $p<.001$).

Emotion did not influence N100 parameters, no more than Groups.

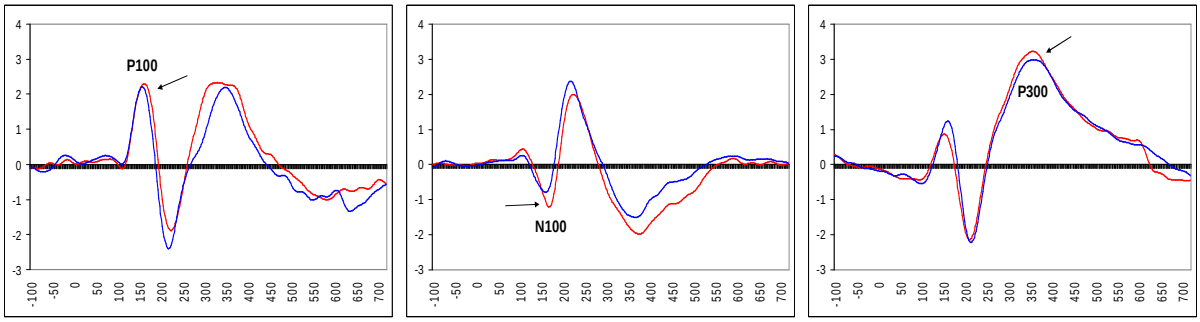


**Figure 38: Grand averaged waveform evoked by arrows at central electrodes for valid (blue line) and invalid (red line) trials in all participants (N=28). Validity effects are illustrated by delayed latencies for invalid trials on P100 and N100 and P300 components.**

3.4.2. P100

The 2 (validity) x 5 (emotion) x 2 (Visual Field) x 3 (Electrode Position) x 2 (group) ANOVA performed on the latencies of the P100 component recorded on O1, Oz and O2 electrodes for occipital cortex revealed a main effect of Validity on latencies ($F(1,26)=4.942$, $p=.035$) with slightly earlier P100 for valid (152ms) than for invalid probes (156ms).

Moreover, an interaction between Visual Fields and Electrodes positions in latency ($F(2,52)=46.230$, $p<.001$) and amplitude ($F(2,52)=15.120$, $p<.001$) reflected higher amplitudes and delayed latencies in the ipsilateral hemisphere.

A significant interaction between Validity x Emotion x Electrodes Positions x Groups ($F(8,208)=3.240$, $p=.026$) outline a tendencies to SAP to

produce higher amplitude in all conditions (see Table 18). However, these increases mainly concerned left electrodes for invalid probe and right electrodes for valid probes, as demonstrated by subsequent *t*-test (significant for Valid Neutral on O1 and Oz ($p$=.033 and .022), Invalid Disgust on O2 and Oz ($p$=.02 and .041), Invalid Fear on O2 and Oz ($p$=.014 and .026), and Valid Fear on O1 ($p$=.021).

#### 3.4.3. P300

The 2 (validity) x 5 (emotion) x 2 (site of recording) x 2 (group) performed on the latencies of the P300 component recorded on P3, Pz and P4 for parietal cortex revealed main effects of Visual Field ($F$(1,26)=9.478, $p$=.005) and Electrodes Position ($F$(2,52)=8.77, $p$=.001): P300 was delayed for target appearing in the right hemifield (377ms vs 362ms), and appeared earlier on right electrodes (359ms) as compared to left (378ms; $p$=.001) or midline electrodes (371ms; $p$=.005).

A significant interaction between Visual Field x Validity ($F$(1,26)=4.953, $p$=.035) indicated a larger delay for invalid probe presented on the right or left visual field (356 vs 379ms) as compared to valid probe (368 vs 374ms).

The same analysis conducted on P300 amplitude revealed a main effect of Electrode Position ($F$(2,52)=13.697, $p$<.001) with enhanced waves on midline electrodes (5.017µV) as compared to left (3.842µV, $p$<.001) or right electrodes (4.356µV, $p$=.008 – comparison with left position, $p$=.041). Significant interactional effects between Visual Field x Electrode Position ($F$(2,52)=3.923, $p$=.038) and between Validity x Visual Field x Electrode Position ($F$(2,52)=5.867, $p$=.015) meant that influence of electrode position

was higher for probes presented on the right hemifield in the case of invalid trials, but comparable for left and right valid probes. Moreover, a Visual Field x Electrode Position x Groups interaction ($F(2,52)=4.206$, $p=.042$) demonstrated that this tendency was exacerbated in SAP.

Emotion did not act on P300 parameters.

### 3.5. Correlation

To test whether P100/N100, N170, P200 and N300 recorded in response to faces on the one hand, and P1/N1 and P3b related to target processing on the other hand, are the successive steps of a continuum in cognitive processing, Pearson's correlations were performed between these components, for amplitude and latency.

The results, shown in Table 19, clearly confirm that the latencies and amplitudes of components produced in response to cues and target were linked: the greater the delay in latency for cues processing, the greater the delay in latency for target processing.

On the other hand, FNE score was highly correlated to P100 in response to faces (latency : $r=-.465$, $p=.013$ ; amplitude : $r=.496$, $p=.007$) and to target (latency : $r=-.411$, $p=.03$), to N170 amplitude ($r=-.452$, $p=.016$), P200 amplitude ($r=.438$, $p=.02$), and N300 latency ($r=-.726$, $p<.001$). However, state anxiety was also linked to N170 amplitude ($r=-.541$, $p=.003$) and N300 parameters (latency: $r=-.463$, $p=.013$ ; amplitude : $r=.414$, $p=.028$).

**Table 19 : Pearson's correlations and level of significance (*.05 ; ** .01; ***.001) between latencies and amplitudes (*italic*) of ERP waves produced in response to face-cues or probe-arrows.**

| | | ERP waves for Cues | | | | | ERP waves for Targets | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **N100** | **P100** | **N170** | **P200** | **N300** | **N100** | **P100** | **P300** | **TR** |
| **ERP waves for Cues** | **N100** | | 0.749 *** | 0.744 *** | .231 | 0.222 | 0.774 *** | 0.678 *** | -0.094 | 0.137 |
| | | | *-0.623 **** | *-0.376 ** | *-.312* | *0.223* | *0.474 ** | *-0.388 ** | *-0.405 ** | *-0.056* |
| | **P100** | 0.749 *** | | 0.730 *** | -.250 | 0.385 * | 0.694 *** | 0.885 *** | -0.044 | 0.053 |
| | | *-0.623 **** | | *0.316* | *.266* | *-0.055* | *-0.514 *** | *0.834 **** | *0.620 **** | *0.074* |
| | **N170** | 0.744 *** | 0.730 *** | | -.517 ** | 0.292 | 0.630 *** | 0.707 *** | 0.074 | 0.036 |
| | | *-0.376 ** | *0.316* | | *.225* | *-0.337* | *-0.051* | *0.190* | *0.007* | *0.152* |
| | **P200** | 226 | -.104 | -.047 | | -.195 | 0.336 | .058 | -.195 | -.112 |
| | | *-.185* | *.191* | *.108* | | *-.326* | *0.127* | *.029* | *.194* | -.102 |
| | **N300** | 0.222 | 0.385 * | 0.292 | 269 | | 0.336 | 0.372 * | 0.094 | -0.139 |
| | | *0.223* | *-0.055* | *-0.337* | *-.373 ** | | *0.127* | *-0.068* | *-0.071* | *0.295* |
| **ERP waves for Targets** | **N100** | 0.774 *** | 0.694 *** | 0.630 *** | .248 | 0.336 | | 0.692 *** | -0.240 | 0.212 |
| | | *0.474 ** | *-0.514 ** | *-0.051* | *-.160* | *0.127* | | *-0.610 ** | *-0.651 **** | *0.031* |
| | **P100** | 0.678 *** | 0.885 *** | 0.707 *** | .160 | 0.372 * | 0.692 *** | | -0.126 | 0.037 |
| | | *-0.388 ** | *0.834 **** | *0.190* | *.081* | *-0.068* | *-0.610 ** | | *0.733 **** | *0.043* |
| | **P300** | -0.094 | -0.044 | 0.074 | -.121 | 0.094 | -0.240 | -0.126 | | -0.014 |
| | | *-0.405 ** | *0.620 **** | *0.007* | *.260* | *-0.071* | *-0.651 **** | *0.733 **** | | *-0.171* |

## 4. Discussion

The main purpose of this study was to examine the deployment of attentional engagement and disengagement mechanisms regarding emotional faces in a modified dot-probe paradigm. The main results concerned the inability of social anxious participants to take advantage of cue validity. However, this effect seemed less originated in a difficulty in disengaging attention than to an intense attentional fixation: the deeper face processing compromised subsequent processes on target stimuli.

### 4.1. Social anxiety influence on behavioral results

Firstly, we reproduced the expected effect of validity: HCP showed significantly shorter response latencies in valid condition, i.e. when a target followed a cue in the attended location. This effect was neurophysiologically indexed by earlier latencies of N100, P100 and P300 components associated with target processing. These results demonstrate the efficiency of our paradigm to test the emotional cueing, since subjects used the cues to detect targets and improved their performance.

Prima facie, the pattern of influence of emotional cues was the same in both groups. However, further analysis showed that SAP and HCP did not differ in invalid condition, when a shift of the attentional focus is required, but SAP were slower in valid condition. More precisely, SAP were unable to benefit from cues to quicken their responses.

Insofar as the attractiveness of anxious individuals for emotions is widely debated in the literature, this lack of cueing benefit in social anxiety is

particularly challenging. However, several causes may justify this. First, the thesis of a motor slowing, acting as a freezing effect, has been advanced by some authors (Mogg et al., 2008). The perception of emotion, and particularly of negative emotions, acts as a freezing slowing down the motor responses. However, such an effect would have equally affected the two conditions, excluding this explanation. Moreover, there was an exception in the absence of cueing effect in social anxiety. Indeed, SAP showed a benefit of cueing in the case of disgusted face: They detected faster valid as compared to invalid targets succeeding to disgust cues, which suggests that disgusted faces are deeply focused, and that engagement effect acts on the detection of subsequent cue. This result is in line with the hypothesis of a particular status of disgust in social anxiety (Amir et al., 2005; Rossignol et al., 2007, Schofield et al., 2007).

However, we cannot attribute the lack of cueing benefit to disrupted disengagement abilities. The observation of an emotional influence on invalid condition only pleads for a role of attentional disengagement. In this context, if the participants suffering from social anxiety had demonstrated disengagement problems, the invalid condition would have been affected, but their performance in valid condition would have been improved. Consequently, we do not confirm the hypothesis of a disrupted disengagement in social anxiety. The explanation for the lack of cueing benefit is therefore to look at another level of processing, and the ERPs should be able to provide clues about this.

### 4.2. Social anxiety effects on ERP results

The processing of emotional cues by SAP was characterized by three main results.

Firstly, the P100, indexing perceptual processing under the influence of selective attention (Mangun & Hillyard, 1996), was increased in this group. This result of a perceptual enhancement without influence of emotional load is in line with previous reports (Kolassa et al., 2007; Kolassa & Miltner, 2006; Muhlberger et al., 2008; Rossignol et al., Submitted-b; Rossignol et al., Submitted-c) and may suggest that faces constitute threatening stimuli in social anxiety, whatever their emotional valence.

Second, the observation of a strongly increased P200 among SAP sustained this hypothesis. The occipital P200 has been functionally associated with the evaluation of the emotional relevance of a visual stimulus (Carretié et al., 2001a; Dennis & Chen, 2007b) and would index the mobilization of attentional resources (Bar-Haim et al., 2005). If we postulate that all face categories constitute relevant stimuli in social anxiety, then the global enhancement of P200 may reflect a global capture of attention by face cues. This observation contrasts with the assumption of an early vigilance followed by a later avoidance, but rather sustain the hypothesis of a greater attentional engagement (on the P100 wave) followed by an intensified attentional fixation (on P200 wave) (Fox, 2004).

Thirdly, we outlined a delayed but increased N300 in SAP. The N300 has been described as reflecting the processing of emotional load of stimuli (Carretié & Iglesias, 1995). Notably, that wave appears enhanced in response

to anger (Schutter et al., 2004) and fear (Rossignol et al., 2005), and is supposed to be particularly increased in response to emotionally relevant stimuli (Carretié et al., 1997b). In this framework, its enhancement for all categories of facial expressions in social anxiety confirms the particular relevance of faces.

To sum up, the ERP waves associated with the processing of face cues argue for increased perceptual and emotional processes in social anxious as compared to non-anxious participants. Conversely, the N170 was decreased in social anxious participants. As the N170 is functionally referred to the configurale analysis of face components (Bentin et al., 1996), this result could be interpreted as reflecting a perceptual dysfunction in face processing, as reported in some psychopathological states as schizophrenia (Campanella et al., 2006; Herrmann, Ellgring & Fallgatter, 2004). However, this reduction cannot be related to a general visual processing deficit, since early perceptual stages were enhanced in social anxious participants (P100/N100 complex). Conversely, this unexpected reduction of configurale processing may be related to a more analytic processing of information conveyed by the face, but this hypothesis must be tested in further studies investigating the role of structural vs. analytic processing of faces in social anxiety.

In any events, the intensified attentional fixation on face should act on the targets processing of social anxious subjects. Effectively, SAP showed a tendency to produce a greater P100 in response to targets, as in valid as in invalid conditions. This observation is not in line with previous report of diminished processing of targets succeeding to emotional faces in social

anxiety (Mueller et al., 2008; Rossignol et al., Submitted-c). However, these studies presented two faces as cues. Consequently, the role of engagement and disengagement processes in this attentional reduction was difficult to disentangle. The present design presented a single lateralized cue. Therefore, if the P100 enhancement had been limited to the attended (valid) location, we would have concluded to an enhanced engagement, while a diminished P100 in unattended location would have been attributed to disengagement disabilities. For instance, HCP showed delayed P100 and N100 in invalid condition, which may reflect the delay in the implementation of attentional resources required by the attentional shift. SAP displayed a similar delayed process, but they produced increased perceptive processes in these two conditions. Consequently, the lack of specificity of this increase may reflect an enhanced sensitivity to visual stimuli (Kolassa et al., 2009).

The hypothesis of a hypersensitivity to incoming visual stimuli also supports the thesis of an arbitrary selection of relevant information and a lack of control over their processing (Bishop, 2007). Indeed, to perform a task efficiently, it is important to inhibit the processing of irrelevant information. A disrupted cognitive inhibition of anxious subjects has already been proposed (Cooper & Langton, 2006; Fox et al., 2005; Wood et al., 2001). This hypothesis links with the theory of a reduced control of the frontal lobes in relation to trait anxiety. This model, originally proposed by Bishop (2007), proposes a suractivation of amygdala in state-anxiety and a decreased prefrontal activity related to trait-anxiety. These deficits would result in an enlarged selection of stimuli considered as threatening, coupled with an

inability to inhibit their processing. Recently supported by data from Schirmer & Escoffier (In Press), the theory of a reduction of prefrontal control seems to apply to social anxiety, which calls for construction of models common to these disorders (Bar-Haim et al., 2007).

The theory of cognitive inhibition failure could also explain the lack of cue benefit on behavioral performance. Indeed, the higher P200 in SAP has been interpreted as an increased attentional anchorage towards faces. In that framework, the increased perceptive processing of targets succeeding to faces, though tendencial, may be seen as a lack of top-down control on the initial redirection of attention after the deployment of attentional resources to process faces. This hypothesis is in line with the proposition of Bar-Haim et al. (2005), who reported an increased attentional dwelling on the face cues trait-anxiety, leading to a slow detection of targets in an attention-shifting task.

On the opposite, the strategic processing step indexed by the P300 wave did not appear to be modulated by social anxiety. Indeed, previous reports show that social anxiety affects earlier stages of information processing, but that later stages are not affected (Rossignol et al., Submitted-a; Rossignol et al., Submitted-b).

### 4.3. Conclusion and perspectives

Before to conclude, we have to recognize that the absence of electrophysiological modulations concerning the processing of the different emotions is to say the least disconcerting. Indeed, the EFE type did not modulate early perceptual or attentional waves, no more than components

related to emotional appraisal, and there was no major behavioral modulation related to the emotional cues.

Accordingly, the division of attentional resources required by the processing of several distinct EFE could be responsible for the lack of obvious emotional effect. This proposal, already advanced in earlier studies (Calvo & Nummenmaa, 2008; Rossignol et al., Submitted-b; Rossignol et al., Submitted-c) suggests that the contrast effects appearing between two emotions, one negative and one positive, are less marked when several negative emotions enter into competition. To investigate this hypothesis, it would be interesting to replicate this design in opposing emotions such as anger and disgust, which seems particularly relevant in social anxiety (Rossignol et al., 2007).

To sum up, this study demonstrated an increased face processing in social anxiety and stressed the role of attentional mobilization and specific emotional processing (P200, N300), congruently with previous reports (Bar-Haim et al., 2005; Dennis & Chen, 2007; Rossignol et al., Submitted-a; Rossignol et al., Submitted-b). Moreover, this attentional anchorage disrupted the implementation of a subsequent task (Bar-Haim et al., 2005). These results are opposed to a theory of vigilance / avoidance but confirm the role of attentional disengagement functions and overall the implication of cognitive inhibition.

## Introduction à la quatrième question de recherche

Considérées ensemble, les cinq études précédentes nous offrent les informations suivantes : l'anxiété-trait semble s'associer à des perturbations assez tardives du traitement de l'information portée par les visages émotionnels. En effet, celles-ci n'affectent pas les étapes perceptives ou attentionnelles du traitement de l'information dans le cas d'une anxiété-trait isolée, mais plutôt les processus associés à la production d'une réponse motrice. Par contre, l'anxiété sociale donne lieu à des modifications précoces, qui non seulement affectent les processus à l'œuvre lors d'une détection de déviance sans pertinence particulière de l'émotion pour la tâche, mais aussi le traitement de cibles succédant à ces visages lorsque ceux-ci doivent être utilisés comme indices. En effet, lorsque deux visages sont présentés de part et d'autre de l'écran, les sujets anxieux produisent des composants perceptifs accrus et effectuent une évaluation émotionnelle plus rapide des paires de visages. Cependant, les sujets anxieux sociaux se révèlent dans l'incapacité de bénéficier de ces indices pour améliorer leur performance dans une tâche de détection de cible de type dot-probe.

Dans le but de nous rapprocher d'une réalité clinique, nous avons esquissé une dernière question de recherche, visant à explorer les interactions entre un état anxieux et un état déprimé, donnant lieu à une dysphorie générale. Dans la littérature, la fréquente comorbidité entre anxiété et dépression a été soulignée et a donné lieu à la définition d'un état mixte anxieux-dépressif. (Barlow & Campbell, 2000; Mineka et al., 1998; Stahl, 1993). Un intérêt croissant est actuellement consacré aux caractéristiques

cognitives de ce désordre, et une question majeure concerne le traitement émotionnel qui lui est associé. Il a en effet été démontré que le cumul d'un état dépressif et d'un état anxieux modifiait les performances cognitives dans différentes tâches (Bouhuys, Geerts & Mersch, 1997; Gilboa-Schechtman et al., 2005; Grant & Beck, 2006; Pierson, Ragot, Van Hooff, Partiot, Renault & Jouvent, 1996; Tarsia, Power & Sanavio, 2003), mais les études cliniques et expérimentales envisagent le plus souvent ces deux désordres de façon indépendante. Nous nous sommes déjà largement attardés sur la perception des EFE dans l'anxiété, mais il convient à ce stade d'évoquer succinctement les données relatives au traitement des EFE dans la dépression. Un biais cognitif négatif a été décrit par certains auteurs qui ont pu mettre en évidence une attribution accrue d'émotions négatives et une réduction d'attribution d'émotions positives chez les individus déprimés (Bouhuys, Geerts & Gordijn, 1999; Gotlib, Krasnoperova, Yue & Joormann, 2004). D'autres, par contre, rapportent une attention spatiale réduite aux EFE positives mais non aux expressions négatives (Suslow, Junghanns & Arolt, 2001), ainsi qu'une sensibilité réduite aux stimuli de valence positif comme par exemple les visages exprimant la joie (*déficit hédonique*) (Sloan, Strauss & Wisner, 2001).

Il semble donc bien que dépression et anxiété soient associées à différentes perturbations de l'information émotionnelle (Mathews & MacLeod, 1994), incluant des biais ou déficits dans la détection et la reconnaissance d'expressions faciales émotionnelles portant sur la menace dans l'anxiété, et sur les émotions positives et/ou négatives dans la dépression (Philippot et al., 2003). La littérature suggère en outre que la comorbidité entre anxiété et

dépression pourrait conduire à une nouvelle catégorie de biais dans la perception des EFE, mais ce domaine n'a été que peu investigué.

Dans le but d'une meilleure compréhension des mécanismes cognitifs à l'œuvre dans la génération des biais émotionnels, il nous paraissait nécessaire de considérer l'interaction de ces deux dimensions cliniques majeures dans la perception de stimuli aussi critiques pour la genèse et le maintien de ces troubles que les EFE. Dans cette perspective, il nous semblait nécessaire d'adresser plusieurs questions :

a) Le biais observable dans les états anxieux-dépressifs est plutôt de nature attentionnelle comme décrit dans l'anxiété seule (Mogg & Bradley, 1998), ou plutôt élaboratif comme décrit dans la dépression seule (Mathews & MacLeod, 1994) ?

b) Quel type d'information émotionnelle en est affecté ? En effet, si l'orientation du biais envers l'information menaçante est établie dans l'anxiété, la direction du biais dans la dépression reste sujette à controverse (*hedonic deficit* vs. *negative cognitive bias*, Nandrino, Dodin, Martin & Henniaux, 2004)

c) A quelle étape du traitement émotionnel un éventuel déficit se marque-t-il dans les états mixtes anxieux-dépressifs, à une étape attentionnelle ou décisionnelle ?

d) Plus globalement, quelles sont les différences évoquées par un état anxieux et un état mixte anxieux dépressif à un niveau cognitif, et comment ces différences s'observent-elles sur un plan électrophysiologique ?

Pour répondre à ces questions, nous avons conçu une étude sur le modèle du paradigme de détection de déviance utilisé dans les chapitres 4 et 5. Afin de vérifier un éventuel biais de détection général et non spécifique aux émotions, nous avons adjoint une nouvelle catégorie de stimuli rares déviants, à savoir un visage différant sur le plan de l'identité et non plus de l'émotion. Dans l'optique de contraster l'anxiété isolée et la mixité anxiété-dépression, trois groupes ont été constitués : un groupe de participants ne rapportant ni anxiété ni dépression, un groupe de participants rapportant une anxiété trait mais pas de plainte dysphorique, et un groupe cumulant anxiété-trait et plaintes de nature dépressive.

# Chapitre 9 :

# Impact d'une comorbidité dépressive sur le traitement émotionnel

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Rossignol, M., Philippot, P., Crommelinck, M. & Campanella, S. (2008). Visual processing of emotional facial expressions in mixed anxious-depressed subclinical state: An event-related potentials study on a female sample, Clinical Neurophysiology/Neurophysiologie Clinique, 38(5), 267-275.

## Abstract

Controversy remains about the existence and the nature of a specific bias in emotional facial expression processing in mixed anxious-depressed state (MAD). Event-related potentials were recorded in the following three types of groups defined by the Spielberger state and trait anxiety inventory (STAI) and the Beck depression inventory (BDI): a group of anxious participants (n = 12), a group of participants with depressive and anxious tendencies (n = 12), and a control group (n = 12). Participants were confronted with a visual oddball task in which they had to detect, as quickly as possible, deviant faces amongst a train of standard neutral faces. Deviant stimuli changed either on identity, or on emotion (happy or sad expression). Anxiety facilitated emotional processing and the two anxious groups produced quicker responses than control participants; these effects were correlated with an earlier decisional wave (P3b) for anxious participants. Mixed anxious-depressed participants showed enhanced visual processing of deviant stimuli and produced higher amplitude in attentional complex (N2b/P3a), both for identity and emotional trials. P3a was also particularly increased for emotional faces in this group. Anxious state mainly influenced later decision processes (shorter latency of P3b), whereas mixed anxious-depressed state acted on earlier steps of emotional processing (enhanced N2b/P3a complex). Mixed anxious-depressed individuals seemed more reactive to any visual change, particularly emotional change, without displaying any valence bias.

## 1. Introduction

The recognition and production of emotional facial expressions (EFE) appear prominent in human's social interactions. They have been extensively investigated among normal individuals in the last few decades (Ekman, 1999). Due to the optimal temporal resolution of event-related potentials (ERP), several visual ERP components were shown to be modulated by emotional category:

• the P100/N100 waves, which are typically described as reflecting primary visual analyses (Mangun & Hillyard, 1996) ;

• the N170, recorded at occipitotemporal sites and reflecting the structural encoding of faces (Batty & Taylor, 2003; Campanella et al., 2002b) ;

• the N2b/P3a occipitofrontal complex, which is maximally recorded around 250 ms and reflects the voluntary switch of attention operated by a subject attending to deviations (Patel & Azzam, 2005);

• the P3b, which peaks at parietal sites around 450 ms, and indexes different functions such as cognitive closure and premotor decisional response-related stages (Bentin et al., 1999; Hansenne, 2000a; Polich, 2004). ERP studies reported alterations in both anxiety and depression, respectively. On the one hand, anxiety studies suggest the presence of vigilance biases throughout different paradigms (Carretié et al., 2004b; Weinstein, 1995). For instance, when subclinically anxious individuals (without depressive tendencies) had to detect deviant emotional faces among neutral ones, early waves and attentional stage were not modified, but anxiety was associated with an earlier P3b component (Rossignol et al., 2005). Conversely,

individuals with social phobia demonstrated enhanced right temporoparietal N170 amplitudes in response to angry faces in an emotion identification task (Kolassa & Miltner, 2006). On the other hand, ERP studies often reported a delay or a reduction of P3b in clinical depression (Bange & Bathien, 1998; Kayser, Bruder, Tenke, Stewart & Quitkin, 2000). Lately, Cavanagh and Geisler (2006) found that P3b was reduced in amplitude and latency when individuals with depressive tendencies processed happy faces as compared to fearful faces, suggesting that happiness was less salient and more difficult to classify than fear.

Recently, researchers outlined the frequent comorbidity between anxiety and depression, developing the concept of "mixed anxiety-depression" (MAD) (Heller & Nitschke, 1998; Mineka et al., 1998). Increasing attention is being given to the cognitive features of this disorder, and a major question pertains to the way emotions are processed in mixed depressed-anxious states. For example, Bouhuys et al. (1997) postulated that anxiety coupled with depression leads to an increased perception of negative EFE in ambiguous faces. More recently, Suslow, Dannlowski, Lalee-Mentzel, Donges, Arolt & Kersting (2004) found that depressed people without comorbid anxious disorder were not impaired in the detection of negative faces, but that MAD patients were slower to respond to positive faces, suggesting that anxiety disorder may lower the efficiency of visual search for positive faces. ERP studies have also stressed the role of comorbid anxiety, by showing differential activation patterns and P300 specific alterations by anxiety

cumulated to depression (Bruder, Kayser, Tenke, Leite, Schneier, Stewart & Quitkin, 2002; Pierson et al., 1996).

These recent observations stress the importance of considering how two major clinical dimensions - depression and anxiety - might interact in their impact on EFE processing, even at a subclinical level. In order to investigate this issue, we used an emotional oddball paradigm, in which participants are confronted with series of frequent standard stimuli and have to detect infrequent deviant stimuli.

The first aim of this study was to test whether "subclinical" MAD individuals showed an impaired processing of emotional faces in general, or whether the impairment of emotional processing is specific to either positive or negative emotions. To this aim, we compared target stimuli depicting the same identity as the neutral frequent ones but displaying a sad or a happy expression with target stimuli portraying a different identity. A general impairment would give rise to both identity and emotional changes, whereas an emotion-specific deficit would be observed only for positive and/or negative emotions. Moreover, we aimed to investigate the specific role of mixed anxious-depressed state in cognitive processing by comparing differences between anxious state and anxious-depressed state at a cognitive level. We observed three groups of participants in order to isolate the effect of anxiety alone and MAD state: individuals with anxiety alone, individuals with anxiety coupled with depression, and individuals without anxiety or depression. Because threatening stimuli were not used, we expected a quicker detection of all deviant stimuli in individuals with anxiety alone compared to

the two other groups, due to general speeded processing (Fox, 2002). In MAD state, we hypothesized a wider alteration of ERP components, appearing since attentional stage and persisting until decisional closure processes, forasmuch as perceptual processes have been involved in anxious-depressed patients (Pierson et al., 1996), but also a more specific alteration of emotional process.

Our second goal was to locate the origin of potential emotional biases in the information processing stream. Studies reported a deficit in P300 in psychopathological states (Bange & Bathien, 1998; Cavanagh & Geisler, 2006; Hansenne, 2000b; Kayser et al., 2000), but if the subjacent deficit is circumscribed to response-related stages, it might also originate from lower level of processing, and extend to the overall process (Foxe et al., 2005). Because depression and anxiety alone are known to affect the processing of emotional stimuli, we hypothesized a modification of ERP components and, more specifically, the P3b wave in MAD states. These modifications could be sustained either by an attentional alteration as in anxiety (Mogg & Bradley, 2002), with a deficit starting at the voluntary attentional level on the N2b component, or by a disturbed elaborative process as in depression (Mathews & MacLeod, 1994), with a perturbation restricted to the P3b component.

## 2. Materials and methods

### 2.1. Participants

Thirty-six students from the faculty of psychology of University of Louvain took part in the experiment. They were selected from a sample of 180 students according to their scores on French versions of the Spielberger State and Trait Anxiety Inventory Spielberger et al., 1983, and of the 13-items Beck Inventory Scale (BDI) (Beck & Beamesdefer, 1974). Given the higher prevalence of anxiety and depression in women (Halbreich & Kahn, 2006) and that gender is known to affect EFE processing (Campanella et al., 2004), we decided to select only female participants. All participants were right-handed, between 18 and 28 years of age, with normal/corrected vision, and without neurological disease.

Participants scoring above 56 on trait anxiety (STAI-T - Spielberger et al., 1983) were classified as anxious, and the BDI cut-off scores used to define if the depressive tendencies were 10 and higher (Furlanetto et al., 2005). On these bases, we constituted three groups of 12 participants: normal control participants (CS), high anxious participants (HA), and high anxious participants with depressive tendencies (MAD). Group characteristics are reported in Table 20.

**Table 20 : Psychological characteristics of MAD, HA and CS participants.**

| | CS | HA | ADT |
|---|---|---|---|
| **Age** | 22.08 (2.61) | 22.25 (2.95) | 21.66 (1.97) |
| **Beck Score** | 1.58 (2.06) | 6.08 (1.73) | 14.58 (4.46) |
| **STAIS** | 42 (9.56) | 57.91 (11.18) | 64 (9.29) |
| **STAIT** | 39.41 (6.07) | 61.08 (7.21) | 63.5 (8.92) |

The experimental procedure used an 'emotional oddball paradigm' (Campanella et al., 2002a; Campanella et al., 2004). Stimuli consisted of six faces (selected from a highly standardized set of pictures from the Ekman and Friesen series (Ekman & Friesen, 1976), with neutral, happy and sad expressions. Participants were to detect as quickly as possible the occurrence of a deviant face among the presentation of standard faces. Standard faces always presented neutral expressions, whereas deviant faces were either the same face displaying an emotion (sad or happy) or a different neutral face (change in identity).

Stimuli, sizing 6 cm horizontally and 8 cm vertically and subtending a visual angle of 3 x 4°, were presented one by one on a black background, and a black screen was displayed as an inter-trial interval, lasting randomly between 1300 and 1600 ms. Eighteen blocks were composed, each defined by 100 stimuli (e.g. 80 frequent stimuli with face A neutral; 5 deviant face A happy, 5 deviant face A sad and 10 face B neutral). The order of the eighteen blocks varied across participants.

### 2.2. Recording

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, but were re-referenced by using a "common average" (Bertrand et al., 1985). 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 kΩ. EEG was continuously recorded (sampling rate 500 Hz, NeuroScan software) and vertical electrooculogram (VEOG) was recorded in a bipolar manner from electrodes placed on the supraorbital and infraorbital ridges of the left eye. Trials contaminated by EOG artifacts (mean of 15%) were eliminated off-line by computing an average artifact 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 artifact-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. Data were off-line filtered with a 30 Hz low-pass filter.

### 2.3. Procedure

During the ERPs recording, participants sat in a chair in a dark room with their head placed 1 m from the screen and restrained in a chin rest. The participants were instructed to signal as quickly as possible the occurrence of

deviant stimuli by pressing a mouse button with their right index finger. Faces were presented for 500 ms, and participants had 1500 ms to answer since stimulation onset. The entire experiment took approximately 50 minutes per participant.

### 2.4. Data analysis

Two parameters were coded for every stimulus: (1) the type of stimulus (rare happy; rare sad; rare identity in order to have the same number of averaged frequent stimuli, only the frequent stimuli preceded the deviant ones); and (2) the type of response (keypress for deviant stimuli, no keypress for frequent ones). This coding allowed for the computation of different averages of ERP target stimuli. The averages were made for each participant individually. Peaks of interest are described subsequently.

Statistical analyses were computed using Statistical Package for Social Sciences, 14th version (SPSS 14.0). We conducted repeated-measures ANOVA (more details will be provided in 3.3 and 3.4 points). Greenhouse-Geiser epsilon correction was used to compensate for violation of sphericity when appropriate. Simple effects analyses of these factors were explored throughout; Bonferroni post-hoc tests were used when appropriate. The sources of significant interactions were systematically examined through simple effects. The alpha level of significance was set at 0.05 throughout. Eta-squared were equally calculated in order to certify statistical power.

## 3. Results

### 3.1. Psychometrical features

Statistical analysis confirmed that groups were not significantly different with respect to age ($F(2,33)= .167$, N.S.), but BDI Scores differed significantly between the three groups ($F(2,33) = 57.77$, $p < .001$). Analyses confirm that the anxiety level obtained for the STAIT ($F(2,33) = 35.812$, $p < .001$) and the STAIS ($F(2,33) = 15.343$, $p < .001$) did not differ between HA and MAD ($p$=.443 and 1.000, respectively), but that these two groups were significantly different from CS ($p$<.001).

### 3.2. Behavioral data

Behavioral data are presented in Figure 39. The performance was at 98% correct, analyses were thus conducted only on correct response latencies. We observed a main effect of trial type ($F(2,66) = 10.715$, $p$ <.001): All groups detected slower sad stimuli as compared to happy or identity trials (both $p$<.001) without difference between these last stimuli ($p$=1.00). We also obtained a main effect for group ($F(2,33) = 5.86$, $p$ =.007): HA detected rare deviant stimuli more quickly than did CS (respectively: $p$=.007) whereas MAD did not differ from HA ($p$=1.000) and tend to have quicker detection than CS ($p$=.063).

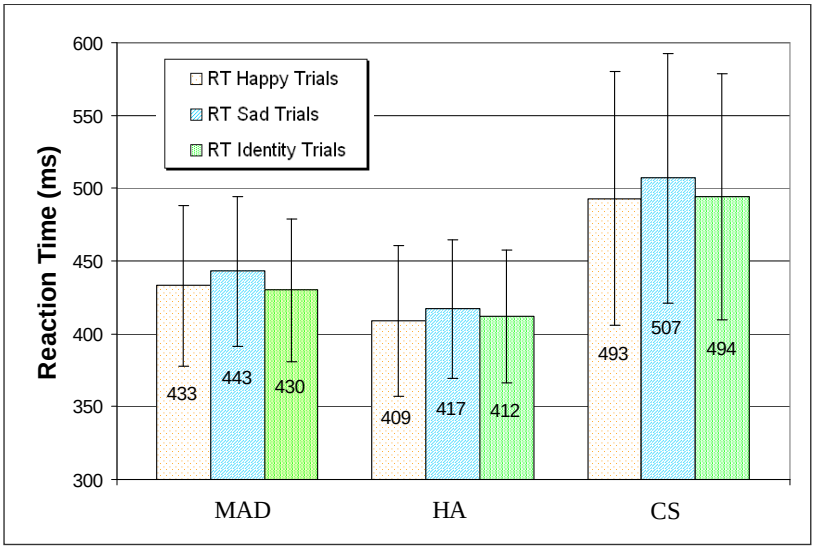


**Figure 39 : Reaction Time (ms) for Deviant Stimuli Detection as a Function of Group.**

Correlation analyses demonstrated significant relationships between reaction time and psychological variables. When all groups were merged together, state and trait anxiety was negatively correlated with reaction time to happy ($r$ =-.493, $p$ = .002; $r$ =-.398, $p$ = .016), sad ($r$ =-.476, $p$ = .003; $r$ =−.400, $p$ = .016) and identity trials ($r$ =-.493, $p$ = .002; $r$ =-.401, $p$ = .015), confirming an accelerated detection of deviant stimuli in people with higher level of anxiety. However, these correlations were nonsignificant inside individual groups.

### 3.3. P100 /N100 and N170 components

Initial visual inspection of the non-subtracted ERP waves suggested different consecutive phases of attention effects (see Figure 40). There were: an occipital P1 enhancement (90—120 ms); a frontal N1 enhancement (90—120 ms); a parieto-temporal N170 effect (140—200 ms).

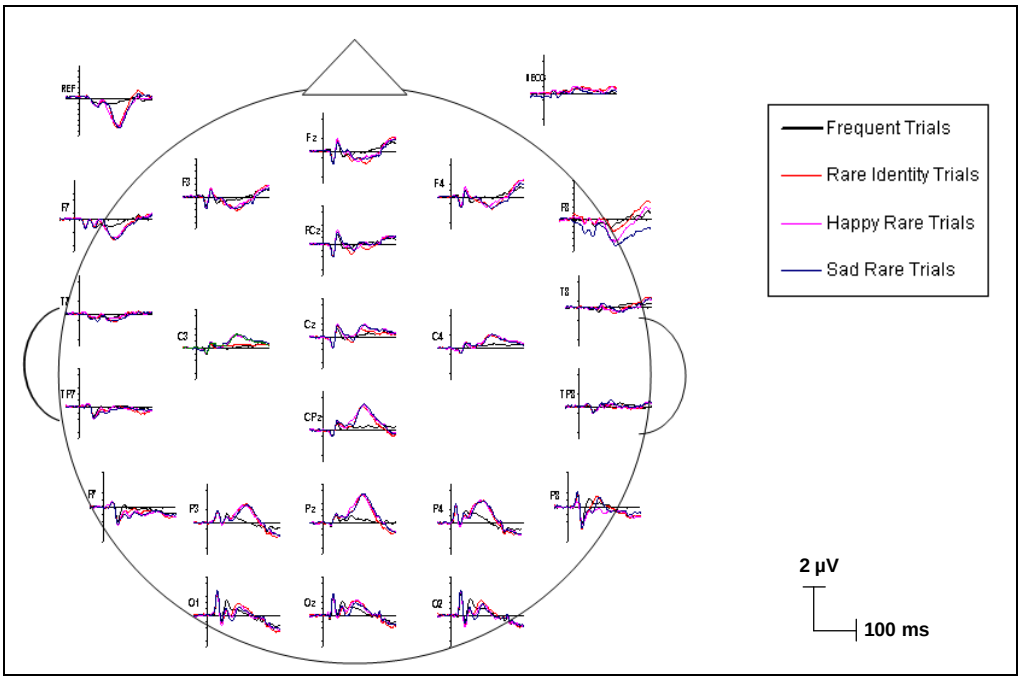


**Figure 40 : Grand Average event-related potentials (ERPs) for frequent (Black line), Rare identity (red line), happy (pink line) and sad (blue line) trials for all groups, on a subset of 22 recording sites, Eye movement channel (HEOG) and reference electrodes. Negative is down.**

The P1 and N1 attention waves were manually identified on the basis of their latency range, topographical distribution and reproducibility from the channels Oz for the P100 and Cz for the N100, in waveforms evoked by frequent and deviant identity, happy and sad stimuli. These measures were submitted to omnibus repeated-measures MANOVA on latency and amplitude, with group (MAD, HA or CS) as between-subjects factor, and trial type (frequent, identity, happy, sad) as within-subject factors. We did not observe any significant effects on early P100/N100 waves. N170 was manually identified at the TP7 and TP8 electrodes. These measures were submitted to two repeated-measures MANOVAs on latency and amplitude, with group (MAD, HA or CS) as between-subjects factor, and trial type

(frequent, identity, happy, sad) and laterality (left or right) as within-subject factors. Statistical analysis did not reveal any significant effect of latency on this wave.

Amplitude was only influenced by trial type ($F(3,93) = 19.288$, $p < .001$) in such a way that N170 was larger for deviant stimuli, emotional or not, than for neutral frequent stimuli ($p \leq .001$ in all cases). However, amplitudes of rare stimuli did not differ according to displayed emotions.

### 3.4. N2b/P3a and P3b effects

Figure 41 represents the regular oddball components observed in all groups for the rare minus frequent stimuli condition. Firstly, negativity was maximally recorded around 230 ms at Oz, with a positive counterpart recorded around 220 ms at Fz. The waveforms and topography allow to identify this bipolar complex as the well-described N2/P3a complex, observed for instance by Campanella et al. (2002a). Second, positivity was recorded around 450 ms, and was identified as the P3b component.

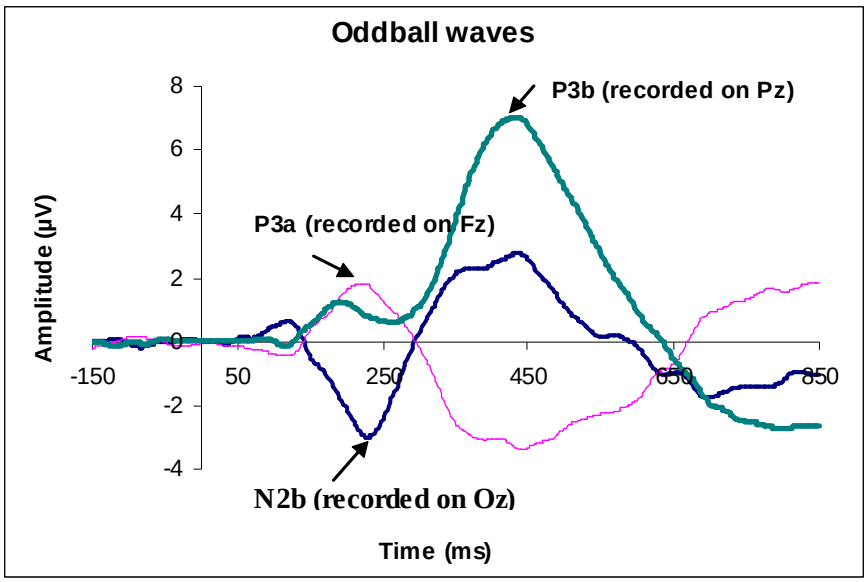


**Figure 41 : Classical oddball waves, N2/P3a and P3b, recorded in the three groups on Oz, Pz and Fz, and obtained by means of the subtraction RARE stimuli – FREQUENT stimuli.**

For N2b (peaking between 200 and 300 ms, occipital distribution on Oz), P3a (same time distribution on Fz) and P3b (peaking around 450 ms at the parietal site Pz) components, individual peak amplitudes and peak latencies were manually identified on the basis of their latency range, their topographical distribution and their reproductibility from median channels for the ERPs resulting from the subtraction of waveforms evoked by standard and deviant stimuli (see Figure 42 and Figure 43). Theses values were tested using omnibus repeated-measures MANOVAs on latency and amplitude, with group (MAD, HA or CS) as between-subjects factor, and Trial Type (Identity, Happy, Sad) as within-subject factors.

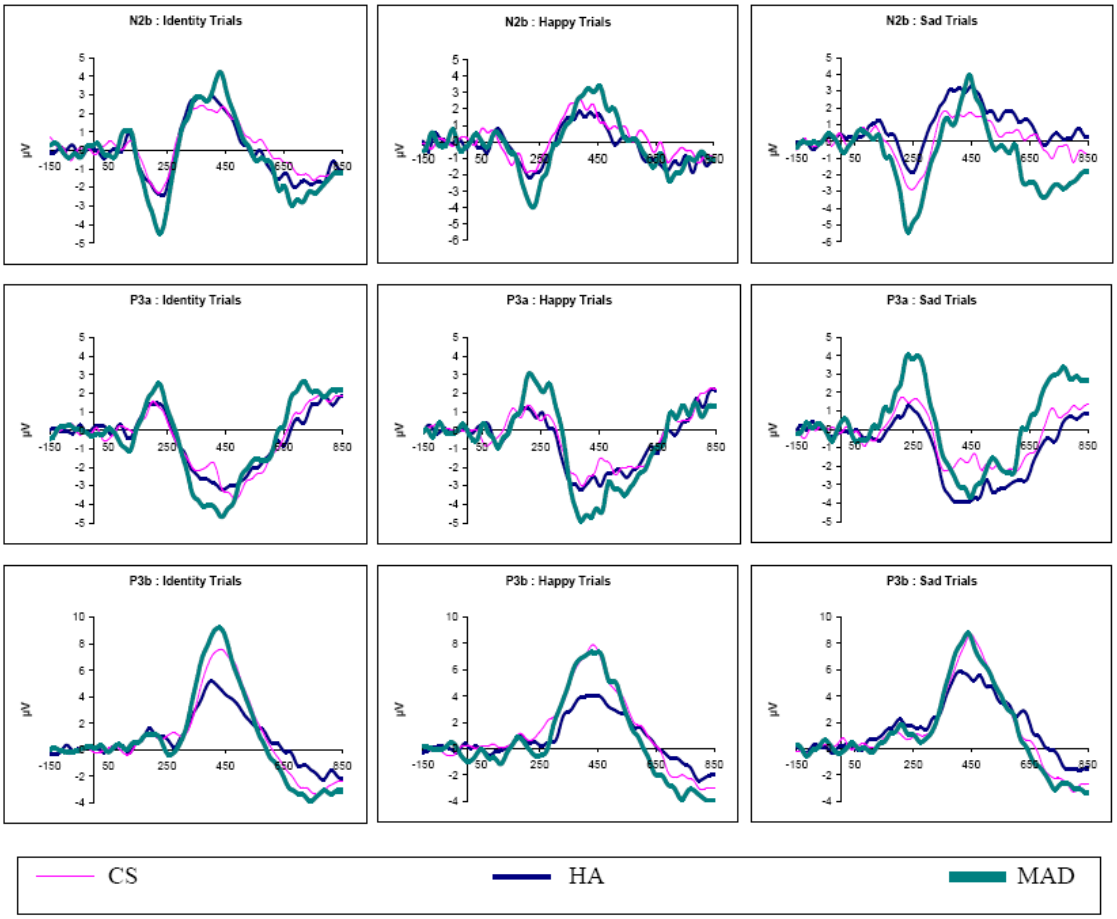


**Figure 42 : Subtraction of waveforms evoked by standard from those evoked by deviant stimuli in response to the two groups of emotional stimuli (happy, sad and identity trials). Negative is down.**

A significant main effect of type of stimulus was observable on N2b latency ($F(2,66) = 16.224$, $p < .001$) : sadness (245ms) evoked later N2b peak than happiness (220ms; Bonferonni comparison : $p < .001$ ) or identity (225ms; Bonferonni comparison : $p < .001$), without difference between these last stimuli ($p = .804$). N2b amplitude was affected by group membership ($F(2,33) = 3.93$, $p = .029$), and Post-hoc tests (Bonferroni) showed that N2b was maximally recorded in MAD (-5.41µV), as compared to HA (-2.87µV, $p = .047$),

without difference as compared CS (-3.13μV, $p$=.085), these two last groups not differing from each other.

On P3a component, a main trial type effect was observed on latency ($F$(2,66) = 4.642, $p$ =.013) with a later P3a for sad trials (240ms) as compared to happy (222 ms, $p$=.047) or identity trials (219ms, $p$=.041), without difference between these last type of trials.

Trial type had an equal impact on amplitude ($F$(2,66) = 5.756, $p$ =.007): P3a was globally reduced for identity trials (2.313) compared to emotional ones (happy: 3.2μV, $p$=.05; sad: 3.4μV, $p$=.001; no difference between emotional trials: $p$=1.000). This effect is not surprising, given that the emotional trials category was composed of both sad and happy trials; the number of identity trials in the whole experiment was equal to the sum of these two categories. Since the P3a has been associated with a novelty effect, we expected a larger wave in response to emotional trials than for identity trials, two times as frequently (Campanella et al., 2002a). The results confirmed this hypothesis.

More interestingly, a group effect ($F$(2,33) = 5.307, $p$ =.01) was observed: MAD globally produced enhanced P3a (4.3μV) as compared to HA (2.2μV, $p$=.019) or CS (2.4μV, $p$=.032), but there was no difference between these last groups. MAD also produced significantly higher P3a for Sad Rare Face than HA ($p$=.001) or CS ($p$=.006). Finally, the most interesting result was a Group x Type interaction effect ($F$(4,66) = 5.756, $p$ =.022): Only the MAD group produced different amplitudes in response to the different categories of trials ($F$(2,22) = 7.705, $p$ =.008); HA ($F$(2,22) = .247, N.S.) and CS ($F$(2,22) = 1.119, N.S.) did not. More precisely, individuals presenting both

anxious and depressed symptoms showed enhanced P3a for happy (4.6µV,) and sad (5.4µV) trials relative to identity trials (2.9µV, LSD contrast : respectively $p$=.048 and $p$<.001). Indeed, this group is entirely responsible of the previously described Trial type effect, since the other groups did not display amplitude differences among trial categories. Correlation analyses showed that state anxiety was positively associated with P3a amplitude, both for happy ($r$=.430, $p$=.009) and sad trials ($r$=.419, $p$=.011) but not for identity trials ($r$=.304, N.S.). P3a amplitude for sad trials was also correlated to Beck score ($r$=-.428, $p$=.009).

Analysis on P3b disclosed a main effect for group on latency ($F$(2,33) = 3.807, $p$ =.033) showing earlier latency in HA as compared to CS ($p$=.043). Correlations revealed a global link between earlier P3b and production of shorter reaction times for happy trials (TR - Pz: $r$ = .370, $p$=.026), and SAD trials (TR - Pz: $r$=.425, $p$=.010), but not for identity trials. Moreover, a within-group correlation revealed that only HA showed these associations (happiness: TR – Pz: $r$=.598, $p$=.04 ; sadness : TR - Pz: $r$=.745, $p$=.005 ; identity : TR - Pz: $r$ = .652, $p$=.022). Psychological variables were associated to P3b latency: latency for sad trials was influenced by state and trait anxiety ($r$=-459, $p$=.005 ; $r$=-.335, $p$=.046), and trait anxiety was also associated to P3b latency for happiness ($r$=-.470, $p$=.004)

Finally, P3b amplitude was affected by Trial Type ($F$(2,66) = 4.362, $p$ =.023): P3b was larger for sad trials (8.6µV) than for happy (7.6µV, $p$=.016) or identity ones (7.7µV, $p$=.03).

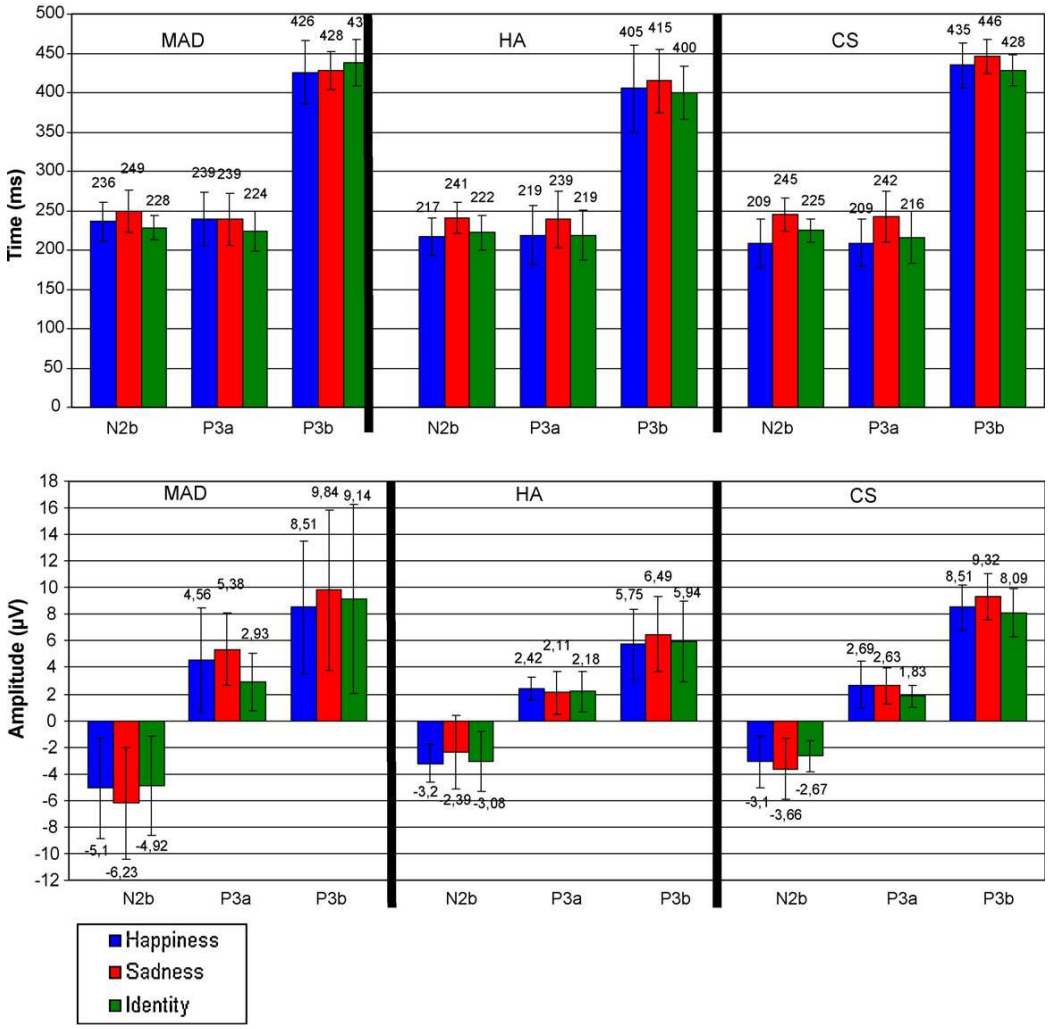


**Figure 43 : subtraction of waveforms evoked by standard from those evoked by deviant stimuli; N2b (recorded on Oz), P3a (on Fz) and P3b (on Pz) latency (Means in millisecond ± SE), and amplitude (Means in microvolt ± SE) for Happy (Blue bar), Sad (Red bar) and Identity (Green bar) Trials. These figures are represented at midline electrodes for the three groups of participants**

## 4. Discussion

The aims of this study were to examine the specificity of the modification of emotional processing in individuals with mixed anxious-depressive tendencies by investigating the role of isolated anxious and comorbid anxious and depressed tendencies; and to investigate the level of occurrence of biases, if any, in the information processing stream.

First, P100 and N100 were not influenced by trial type, contrary to the N170, which appears sensitive to novelty, but not to emotion in facial expressions. This observation supports results reviewed by Eimer and Holmes (2007), who have interpreted the N170 as insensitive to the emotional load of processed faces. Although early waves did not differ between groups, there were clear between-group differences in behavioral performance. Behavioral detection of deviant trials was accelerated in both isolated-anxiety and MAD state, but the mechanisms underlying this faster processing seemed different in both anxious groups. Indeed, for subjects with isolated anxious tendencies, this behavioral reaction was only indexed by faster decisional processing (P3b), supporting the notion of a faster detection of any new information in anxiety (Rossignol et al., 2005).

Conversely, participants with comorbid anxious-depressive tendencies did not show modifications of the P3b wave, but rather an increased attentional processing of the deviant stimuli. Indeed, a global enhancement of N2b was associated with an increased P3a for emotional trials as compared to

identity ones, especially for sad faces. Of course, identity trials were presented twice as much as sad or happy faces, but this effect of an enhanced P3a for emotion processing is only present in MAD group. This observation supports previous evidence of increased involuntary processing of emotional information in depression (Mathews & MacLeod, 1994).

Consequently, it seems that the modification of facial processing in MAD originates in altered earlier attentive stages, and not in disturbed response-related processes. Studies investigating ERP components in depression often concentrated on P3b (Hansenne, 2000b), and the most commonly reported result is a delay or a reduction of P3b in clinical depression (Bange & Bathien, 1998; Kayser et al., 2000). Our results diverge from these observations, and could be attributed either to the subclinical level of depression displayed in our sample of subjects, or to comorbid anxiety. However, studies in subclinical participants found P3 modifications: For instance, Cavanagh and Geisler (2006) observed reduced amplitude and delayed latencies of P3 when subclinical depressed participants had to detect happy faces, as compared to fearful faces, embedded in neutral faces. However, they did not control for comorbid anxiety, which could have enhanced the processing of threatening-fearful expressions. Conversely, since biases occurred when emotional material matched the specific vulnerability of each disorder, sadness did not elicit such more salient processing in anxiety, and the expressions used in our study could explain this discrepancy.

In spite of these observations, we defend the notion that comorbid anxiety plays a role in the differences in observed performance. As supported by different studies (Bruder, Fong, Tenke, Leite, Towey, Stewart, McGrath & Quitkin, 1997; Heller & Nitschke, 1998; Keller, Nitschke, Bhargava, Deldin, Gergen, Miller & Heller, 2000), anxiety and depression are sustained by specific physiological characteristics that lead to different performance patterns, and comorbid anxious-depressed state results in particular biological and physiological correlates (Bruder et al., 2002; Pierson et al., 1996). Therefore, we suggest that the enhanced attentional complex observable in MAD group results of the interaction between anxious and depressed states, since anxiety alone did not arouse such an effect. Our results thus support the hypothesis of a modified processing of affective stimuli in concurrent anxiety and depressed states.

To summarize, our study suggests that the visual emotional processing may be quite different in nature in anxiety and in MAD state, and we highlight two different ways to process visual emotional information in individuals with anxious versus anxious-depressive tendencies. Other studies have been conducted using ERP in anxiety and depression. However, to our knowledge, our study is the first to explore the processing of emotional-faces stimuli in people with concurrent anxious and depressive tendencies using an emotional oddball paradigm.

Although the present study provides some evidences for specific effects of mixed anxious-depressed state, it is important to recognize several

limitations. First, the inclusion of a fourth group constituted by depressive participants without anxious tendencies would have been useful to address the exact contribution of anxious and depressive influence separately. However, in our investigations, anxiety was a correlate of depression, and participants showing depressive tendencies always displayed anxious behavior, whereas the reverse was not true. This problem may be related to the subclinical status of the population pool. Another limitation is that the scales used to define these tendencies did not allow for the exploration of specific features of anxiety symptoms, and high correlations between scores on the STAI and BDI scales have already been outlined in past literature (Bruder et al., 1997). Also, because the participants were only subclinical and selected according to criteria of the BDI and STAI, they were not grouped according to a clinical diagnosis, and therefore, we do not know whether one symptom, i.e. anxiety or depression, was more prominent that the other. Finally, because gender differences have been shown in emotional processes (Campanella et al., 2004), and as depression is more prevalent in women (Halbreich & Kahn, 2006), the present study concentrated on female participants; it would be useful to conduct the experiment on male participants.