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Research Report

Categorical perception of anger and disgust facial expression is affected by non-clinical social anxiety: An ERP study

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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

Categorical perception is a well-documented phenomenon in the field of human perception (Harnad, 1987). Categorization consists of allocating different stimuli to discrete categories, where categorical membership is contingent on common properties. Through categorization, linear physical changes are interpreted as having non-linear perceptual effects. This point is best illustrated through an analogy: the color spectrum consists of a variation of light frequencies, but

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individuals perceive chunks of colors rather than a continuum of color change. Furthermore, authors have argued that discriminating between two stimuli that are perceived as stemming from two different categories is generally easier than distinguishing 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 color perception have shown that individuals discriminate between two colors belonging to different categories (blue–green) more easily than two colors belonging to the same category (blue–blue), *even if the physical distance is held constant between each pair* (Harnad, 1987).

This phenomenon is not restricted to simple stimuli; studies have shown that complex stimuli, such as faces, are categorically perceived in terms of emotional expression (Campanella et al., 2002a,b; Etcoff and Magee, 1992; Young et al., 1997). This categorization effect has even been found in 7-month-old infants (Kotsoni et al., 2001). The phenomenon of categorical perception of emotional expression is typically studied by using morphing procedures — artificial continuance of interpolated (morphed) facial expressions deriving from two separate prototypical emotional expressions from the same individual. Campanella et al. (2002a) asked participants to discriminate between three types of face-pairs, which were separated by a constant physical distance. Three types of pairs included two images of the same face (identical pair), two faces displaying two different emotions (between pairs) and two faces displaying the same emotion (within pairs). Results showed that *within pairs* was harder to discriminate than between pairs, even though the physical distance within each pair was kept constant. These findings suggest that performance in perceiving emotion through facial expression is more influenced by the emotion's category membership than by the objective physical distance (Campanella et al., 2002a,b). Tanaka et al. (1998) explain this effect as the existence of different prototypical representations for different emotional facial expressions, which are stored in long-term memory. Different prototypes are activated when individuals see faces portraying different emotional expressions. Thus, morphed faces of between-categorical pairs seem to activate two different representations and facilitate discrimination, whereas within-categorical pairs relate to the same representation and are consequently more difficult to discriminate.

In an electrophysiological study, Campanella et al. (2002a) examined the neurophysiological correlates of this categorical phenomenon and recorded event-related potentials during an "oddball task" using morphed faces displaying fear and sadness expressions. Participants were shown identical stimuli repeated successively and were asked to detect as quickly as possible rare/dissenting stimuli depicting either the same emotion depicted in the frequent stimuli (within-stimuli) or a different emotion (between-pairs), while the physical difference between frequent and rare faces remained constant. Results showed a greater delayed N2b/P3a complex, representing an "attentional orienting complex" (Halgren and Marinkovic, 1995; Suwazono et al., 2000), for responses to deviant stimuli in the within-stimuli condition relative to the between-stimuli condition. The authors also found an enhanced P3a component for between stimuli, purportedly due to increased attention directed towards the rare stimulus displaying a different emotion relative to a frequent emotion. This pattern of neurophysiological results suggests that categorical perception is driven by attentional processes.

Conversely, attention seems easily disrupted in psychopathological states, and research reports widespread evidences of attentional biases in emotional perception (for an example, see Philippot et al., 2003). Attentional biases have been especially established in several anxiety disorders such as generalized anxiety disorder, obsessive-compulsive disorder, specific phobia and, in particular, social anxiety (Mathews and MacLeod, 1994; Mogg and Bradley, 2002). Social anxiety refers to the fear of social situations that imply evaluation and judgment by other people. More precisely, it concerns the fear of being judged and evaluated negatively, leading to a feeling of inadequacy, embarrassment and humiliation (Marcin and Nemeroff, 2003). Given the particular characteristics of this disorder and the specific role played by emotional facial expressions (EFE) in human interactions, numerous studies have used EFE to evaluate biases in individuals with social anxiety. Specifically, this research focuses on attentional biases towards negative stimuli among these individuals (Mogg and Bradley, 2002; Mogg et al., 2004).

Most EFE studies on social anxiety have focused on two emotions, namely anger and fear (Mogg et al., 2004). The interest for these specific EFE is understandable considering angry faces are universally read as a cue for interpersonal threat, whereas fear is a more indirect signal in that it is often interpreted by socially anxious individuals as reflecting the presence of a threat in the immediate environment (Fox, 2002; Surcinelli et al., 2006). Indeed, Öhman (1996) argues that fear responses to biologically aversive stimuli, such 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 socially anxious individuals have demonstrated a vigilance effect for threatening expressions as compared to neutral or positive faces (Mogg and Bradley, 1998; Mogg and Bradley, 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 a hyperfunctioning alert system, with an attentional attraction for threatening stimuli. Extending from this, studies have illustrated a "double-movement" phenomenon in threatening-face 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). These results support a hypervigilance-avoidance theory, implying that individuals with social anxiety initially direct their attention towards threat-relevant stimuli, but subsequently avoid extended gazing towards these stimuli, which suggests a desire to prevent objective evaluation and habituation (Mogg et al., 2004). However, if socially anxious individuals have a bias towards hyper-perception but less extended gazing of threatening faces, they do not misinterpret the threat value of faces (Douilliez and Philippot, 2003; Philippot and Douilliez, 2005). In summary, though socially anxious people detect threatening facial expressions more easily, they should not be expected to find a qualitative difference between these expressions.

While fear has typically been interpreted as the key symptom of anxiety disorders (Woody and Tolin, 2002), disgust also plays a crucial role in the etiology and persistence of a wide range of anxiety disorders (Phillips et al., 1998), including specific phobia, where the phobic object inspires a strong disgust to the subject (e.g. arachnophobia and the fear of spiders, (Charash and McKay, 2002; Woody and Tolin, 2002), obsessive-compulsive disorders (OCD) (Tsao and McKay, 2004) or agoraphobia (Muris et al., 1999)). Lastly, Phillips et al. (1998) postulated a relationship between disgust and social phobia, where disgust and shame are self-directed, in addition to the definitional fear of being publicly humiliated.

Indeed, Amir et al. (2003) argue that disgust could play a more prominent role than anger in social anxiety. That is, a face expressing disgust may evoke thoughts, in the socially anxious individual, of being rejected and humiliated in public (Phillips et al., 1998). Individuals with social anxiety could be more susceptible to misinterpret the non-social expression of disgust because of the more complex nature of their interpretation of disgust, relative to the average individual. In addition, the fear of physical contact with unfamiliar people may also imply disgust and, at 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 is under-investigated. The present study will address two main questions:

1. Are non-clinically socially anxious individuals more sensitive to categorical perception when compared to control participants? Do anger and disgust elicit attentional biases in non-clinically socially anxious subjects?
2. If we find heightened sensitivity in non-clinically socially anxious individuals, does this deficit in emotional process occur at the attentional stage or at a later stage?

In order to address these questions, the present study used the *emotional oddball paradigm*, in which participants are confronted with series of related and *frequent* standard stimuli and are asked to detect deviant or *rare* stimuli (Campanella et al., 2002a, 2004; Rossignol et al., 2005). Using a computer-based morphing program, we generated a continuum of morphed faces moving from one facial expression (e.g. anger) to another (e.g. disgust). As frequent stimuli, we used a face displaying one emotion and asked participants to detect one of two types of deviant faces: one expressed the same expression at a different level of intensity, and a second expressed a completely different emotion. Importantly, the deviant faces were always distant from the frequent one with the physical distance held constant (30%). Moreover, the type/intensity of the emotional expression was the only characteristic differing between rare and frequent stimuli. Using this procedure, we sought out to established the ease with which individuals discriminate disgusted from angry faces (and vice versa), with social anxiety as a moderating variable.

In order to study the temporal processing of information, we measured and analyzed event-related potentials (ERP) (i.e., the brain electrical activity) related to the task. ERP measurement uses observation of waveforms evoked by frequent and rare stimuli in order to distinguish attentional and decisional (or response-related) steps (Rossignol et al., 2005). Different specific ERP components are indeed produced when the participant has to detect and when the participant has to respond to rare stimulations. First, the N2b/P3a wave complex, known as representing an "attentional orienting complex" (Halgren and Marinkovic, 1995; Suwazono et al., 2000), is composed by the N2b component, maximally recorded at occipital sites around 250 ms, and by the P3a, which is recorded at frontal sites. More precisely, the N2b component refers to the attentional shift needed to encode new information (Suwazono et al., 2000), while the P3a component is more sensitive to the degree to which novel stimuli deviate from frequent stimuli (Knight, 1991). Second, when an attended stimulus has been detected, the P3b component peaks at parietal sites around 450ms (Bentin et al., 1999; Hansenne, 2000), which should reflect decision making and premotor response-related stages (Hansenne, 2000; Polich, 2004).

As such, 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 should facilitate an interpretation of the stage of processing at which the bias occurs (Campanella et al., 2004). Consequently, studying evocation of different ERP components in response to the stimuli used in the present study should (1) build on the current understanding of the processing of emotional facial expression and (2) help to elucidate the stage at which the aforementioned processing bias takes place in social anxiety.

2. Results

2.1. Behavioral data

There was a 98% correct response rate. We computed a 2×2×2 ANOVA on reaction time for correct responses, with condition

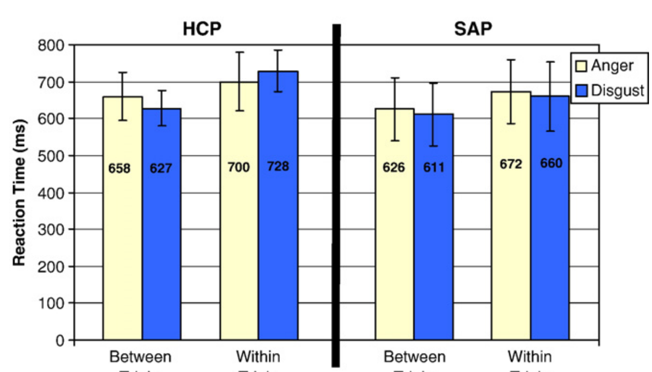

Fig. 1 – Reaction times in detection of deviant faces.

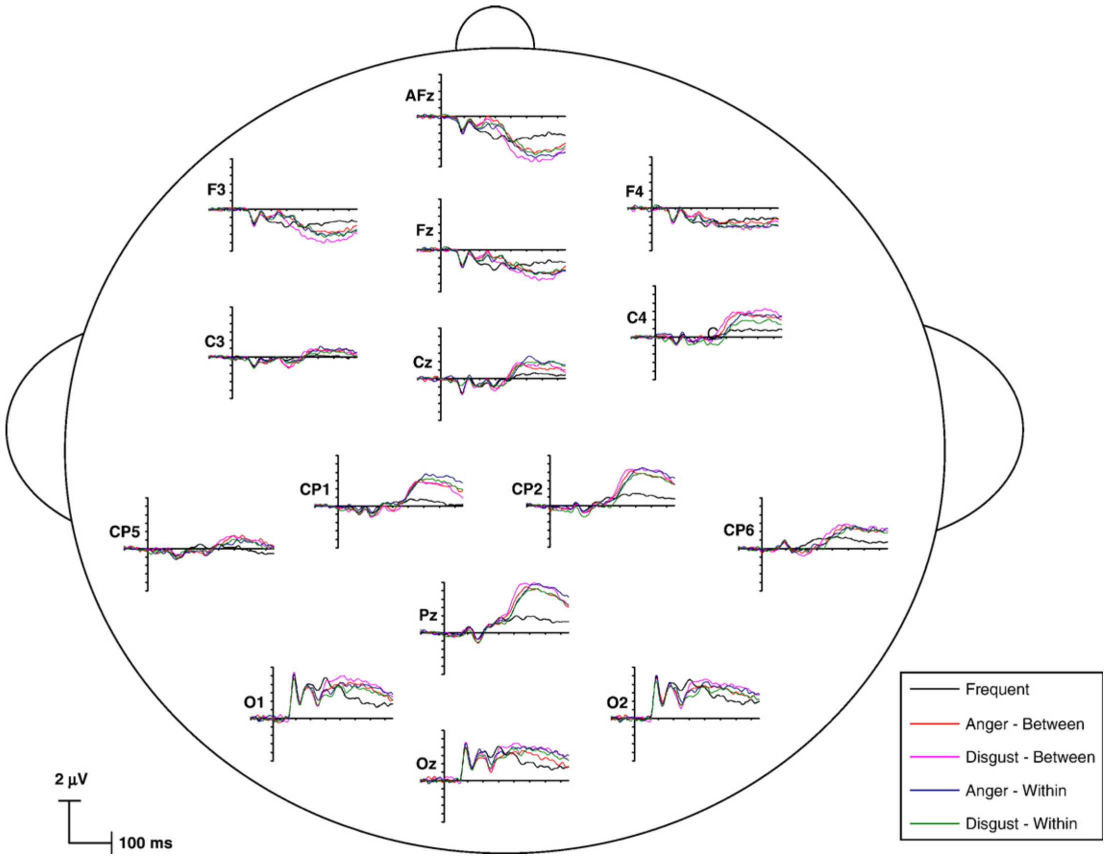

Fig. 2 – Illustration of grand averaged ERPs elicited by standard (black bold line) and deviant stimuli (thin lines) in SAP, for a subset of 15 channels. Negative is down.

(BETWEEN vs. WITHIN) and emotion (anger vs. disgust) as within factors, and groups (HCP or SAP) as a between factor. The results showed a main effect for BETWEEN condition ($F(1,18)=37.513$, $p<0.001$), represented by quicker responses (see Fig. 1) and replicating the classical effect of categorical perception. Second, two interaction effects emerged between condition and emotion ($F(1,18)=6.398$, $p=0.021$). t-tests showed significantly faster detection of BETWEEN trials displaying disgust (interrupting a series of angry faces) ($t(19)=3.131$, $p=0.005$) compared to anger. However, there was comparable detection of anger and disgust on WITHIN condition ($t(19)=0.662$, NS).

Next, a three-way interaction for condition × emotion × group ($F(1,18)=5.252$, $p=0.034$) indicated that anxiety was a moderator for categorical perception, which we explored by subsequent post hoc tests. While HCP showed the interaction effect between condition and emotion described above ($F(1,9)=30.044$, $p<0.001$), SAP displayed the opposed pattern: they showed the classical effect of condition ($F(1,9)=7.313$, $p=0.024$) (similarly than the one displayed by HCP ($F(1,9)=75.229$, $p<0.001$)) and a tendential emotional effect ($F(1,9)=3.824$, $p=0.082$), but no interaction effect ($F(1,9)=0.018$, NS). This trend suggests that disgust tends to be detected before anger (means: disgust=649.4; anger=635.6), independent of conditions. This direct effect is not appearing in HCP ($F(1,9)=0.006$, $p=0.938$) because of the interaction influence.

2.2. Event-related potentials

Fig. 2 illustrates the ERP waveforms obtained for frequent and deviant stimuli. As described in the classic 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 450 ms and reflecting response preparation and closure process (see Fig. 3).

A 2 (conditions) × 2 (emotions) × 2 (groups) ANOVA was computed on each ERP component.[1] They showed that BETWEEN trials always evoked earlier ERP component (see Table 1 and Fig. 3).

First, the analysis on N2b showed a main effect for condition in latency ($F(1,18)=41.04$, $p>0.001$) and a condition × emotion × group interaction on amplitude ($F(1,18)=6.58$, $p=0.019$) (see Fig. 4).

Complementary analyses were performed in order to decompose this complex interaction effect. In HCP, anger

[1] Because we found that our subjects were contrasted on Beck Score, we added depression score as a co-variable in the analyses. However, we did not find any effect related to the depression score.

Table 1 – N2b, P3a and P3b component: 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)

and disgust evoked N2b of similar amplitude in the WITHIN condition ($t(9) = -0.123$, NS), whereas disgust detection tended to evoke larger N2b than anger detection in the BETWEEN condition ($t(9) = 1.999$, $p = 0.077$). This suggests that more attentional resources were required to detect an expression displaying disgust among a series of angry faces than the reverse situation. However, SAP showed a different pattern. Here, anger and disgust elicited comparable N2b in the BETWEEN condition ($t(9) = 0.102$, NS), but disgusted faces tended to evoke enhanced N2b as compared to angry ones in the WITHIN condition ($t(9) = 2.011$, $p = 0.075$). Moreover, when we compared neural responses to angry faces in the WITHIN condition, HCP tended to produce an enhanced N2b response as compared to SAP ($t(18) = -1.971$, $p = 0.064$). Indeed, disgust detection was comparable in SAP and HCP conditions (*t*-tests values were equal to .552 and .337 for BETWEEN and WITHIN conditions, respectively). However, more anxious participants exhibited a diminished N2b in response to degree of anger expression (WITHIN condition) relative to control participants.

P3a latency was also influenced by condition ($F(1,18) = 46.313$, $p < 0.001$) and was shorter for BETWEEN trials. We found a group × emotion effect ($F(1,18) = 3.847$, $p = 0.065$) where HCP and SAP did not differ on P3a latencies for anger ($t(18) = 0.342$, NS), but SAP produced earlier P3a for disgust ($t(18) = 2.132$, $p = 0.047$).

Lastly, the condition influenced latencies ($F(1,18) = 6.541$, $p = 0.02$) and amplitude ($F(1,18) = 14.212$, $p < 0.001$) of the P3b component, which appeared earlier and was enhanced for BETWEEN trials. A condition × emotion interaction ($F(1,18) = 4.677$, $p = 0.044$) showed that anger and disgust detection

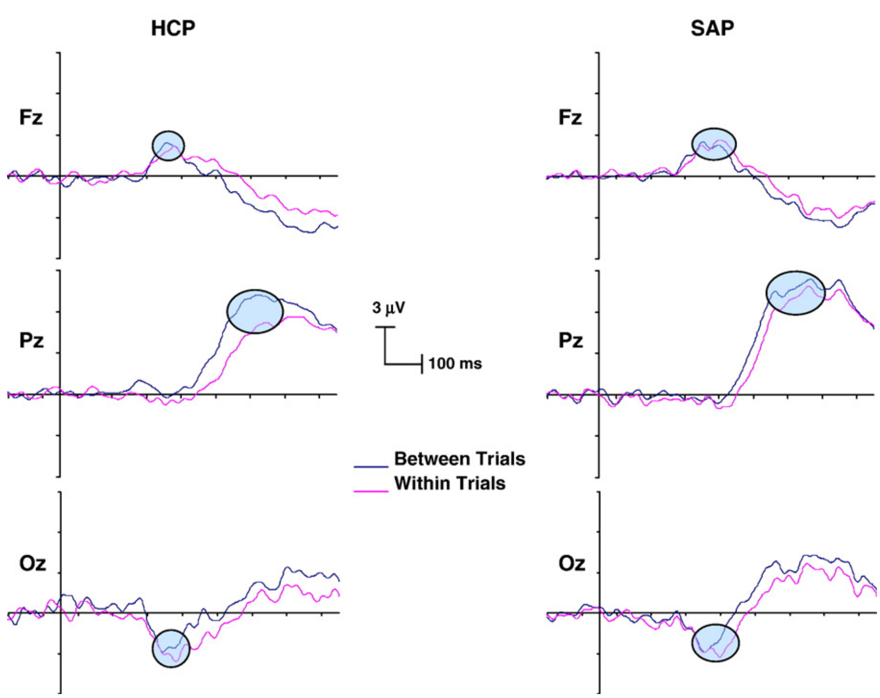

Fig. 3 – Representation of categorical perception effects on ERP waves, in SAP and HCP groups. Blue lines represent BETWEEN condition, and pink lines WITHIN condition. The shaded areas indicate the peaks studied, namely N2b on Oz, P3a on Fz and P3b on Pz. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

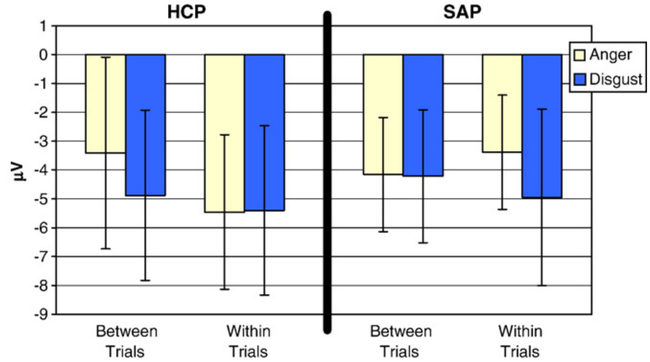

Fig. 4 – Amplitude effects on N2b component related to the level of social anxiety.

evoked similar P3b amplitude in the WITHIN condition ($t(19) = 0.313$, NS), but P3b was enhanced for disgust in BETWEEN condition ($t(19) = 2.794$, $p = 0.012$).

3. Discussion

The categorical perception effect on emotional recognition has been described as an attention-related phenomenon (Campanella et al., 2002a). Research has found that perception biases in individuals with anxiety disorders can moderate typical attentional mechanisms, which alter emotional perception (Bradley et al., 1999; Mathews and 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 behavioral level, and at the neurophysiological level through the N2b/P3a complex.

First, the classic categorical perception effect was reproduced where BETWEEN trials were easier to detect than WITHIN trials and gave rise to shorter reaction times. Therefore, participants discriminated more quickly between faces displaying different expressions than faces displaying the same expression, even when the physical difference between the two faces was held constant (Campanella et al., 2002b; Etcoff and Magee, 1992). This behavioral result was shown on a neurophysiological level 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.

Our second main finding concerns the effect of social anxiety on categorical perception observable on ERP components. Indeed, at a global behavioral level, SAP and HCP showed similar latency in detection of deviant trials among frequent trials, and both groups showed comparable P3b decisional component. This effect is inconsistent with the classically reported observation of socially anxious individuals' accelerated detection of change (Mialet, 2000; Rossignol et al., 2005). However, studies reporting a faster detection of negative emotions in anxiety have often contrasted negative emotional stimuli with neutral or positive stimuli (Bertrand et al., 1985; Fox, 2002; Rossignol et al., 2005). In the present experiment, frequent stimuli were already emotional, but the change to be detected concerned a level of intensity (WITHIN trials) or a change from one negative emotion to another (BETWEEN trials). This key difference in experimental paradigm might explain the absence of a clear behavioral effect related to anxiety level.

The present study found that social anxiety seems to act on specific emotional processing, on a behavioral level. That is, HCP demonstrated a clear influence of condition on emotional detection whereas SAP tended to detect disgust before anger, regardless of condition. This global effect was correlated with an earlier P3a component, reflecting the sensitivity to the degree of novelty of the deviant information (Knight, 1991). One basic interpretation could be that non-clinical social anxiety leads to be more reactive to disgust expression. However, we should consider each condition in turn in order to fully understand social anxiety's influence.

HCP detected disgust among angry faces more quickly than anger among disgust, but SAP did not show any comparable difference in detection. Moreover, electrophysiological results showed clear effects 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 attention toward new information, was particularly influenced by 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, relative to anger detection. On the other hand, the pattern is reversed for WITHIN trials: when the emotion displayed by the deviant stimuli differs only on level of intensity, HCP produced similar N2b for disgust and anger detection, when SAP evoked a reduced N2b for anger, compared to disgust detection. In this WITHIN condition, responses to disgust presented similar amplitude and latency parameters in both groups, 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 and Marinkovic, 1995), we propose that attention load and engagement may explain the divergent effect of social anxiety. Since higher amplitudes are often interpreted as a cue reflecting a level deeper processing (Rugg and Coles, 1995), our results suggest that SAP detect a change within an expression of anger (WITHIN trials) more easily than HCP, which may be explained by the concerns that typify social anxiety. In this task, rare stimuli in WITHIN trials depicted the target emotion on a more intense level (for instance, AAD 5% and 35% were respectively rare and frequent stimuli). In human interaction, if the degree of anger expressed by a face increases during a conversation, it may mean that the threat represented by the person is rising and that precautions must be taken. The efficient observation of such subtle changes is particularly pertinent to individuals with social anxiety. In the context of our study, when SAP have to detect a change in the degree of anger displayed by a face, it seems they have less difficulty in disengaging their attention from the frequent stimuli, which are already displaying anger, but less intensively. Consequently, these individuals require less attentional resources, resulting in a smaller N2b. These results are consistent with the hypothesis of an enhanced ability to detect negative social cues in patients with a high FNE score (Winton et al., 1995). On the other hand, evaluating a change in the degree of disgust depicted by a face may seem less relevant, and SAP required more attentional resources to disengage from the frequent stimuli and detect the infrequent ones. This effect is equally observable on the P3b component, which was enhanced for disgust as compared to anger. This suggests that, among SAP, two expressions of disgust with different intensity were less differentiable than the two expressions displaying anger and needed more cognitive resources to be processed.

For BETWEEN trials, the problem is reversed: HCP tended to produce smaller N2b in order to detect angry faces in a series of disgusted faces, which required less attentional resources than the detection of disgusted faces among angry faces. In this last situation, people need more attentional resources to disengage from faces depicting anger, which, consequently, evoked 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, compared to HCP, SAP evoked similar N2b for anger and disgust detection and allocated the same level of attentional resources to disengaging from frequent faces displaying disgust in order to detect angry faces, relative to detecting angry faces among disgusted faces. SAP did not show the facilitation effect displayed by HCP when they were required to distinguish rare faces expressing anger. Future studies may examine whether SAP subjects would show specific difficulties in disengaging from disgust in this context.

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 disengage attention from the present stimulus, in order to shift attention towards the new location and reengage to this new stimulus (Amir et al., 2003). However, as recalled by Marcin and 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 hypothesized 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 and Nemeroff, 2003; Mathews and 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). Thus, the subjects have to disengage their attention away from faces expressing disgust and direct their attention towards angry faces.

A previous study already outlined difficulties in disengaging attention in social phobia (Amir et al., 2003). In this study, socially relevant threatening words, positive words and neutral words were presented one by one on a screen, in one of 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 that individuals with social phobia had difficulty in disengaging from threat-related words.

An intriguing point is that, in our study, we observed comparable behavior (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 explained by the increased pertinence of disgust expression in social anxiety, as compared to anger. Future studies should investigate this question.

In current literature, disgust recognition has been frequently studied but has not focused on its specificity in anxious disorders. As underlined by McKay (2002, p.475) in an 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, when Surcinelli et al. (2006) asked high vs. low trait anxious participants to evaluate angry, sad, happy, fearful, disgusted and neutral faces, the authors only observed a better recognition of fear in high anxious individuals. This study evaluated conscious, verbal evaluation and found that socially anxious individuals did not show any systematic evaluative differences (Douilliez and Philippot, 2003; Philippot and Douilliez, 2005), but did not address disgust perception. In the same way, studies investigating visual scanpath (Horley et al., 2004) or attentional processing (Mogg and Bradley, 2002; Mogg et al., 2004) often compare angry faces to happy or neutral faces, without consideration of disgust perception. Nevertheless, a recent study using functional magnetic resonance imaging (Amir et al., 2005) has outlined a hyperactivation of the anterior cingulated cortex when subjects with social phobia perceived disgusted faces. These findings suggest 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 angry and disgusted emotional face stimuli in a sample of participants with non-clinical features of social anxiety through the use of an emotional oddball paradigm. However, our data are still preliminary since the participants were only sub-clinical and selected according to criteria of FNE and STAI. That is, 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 subthreshold degree of symptom severity. Moreover, our analyses were computed on two groups composed by 10 individuals each, and some results mentioned were only mildly significant and should therefore be interpreted with some caution. Furthermore, we used faces of only two actors as stimuli. Future studies should confirm these data in larger clinical samples, and with extended sets of stimuli.

In conclusion, 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 subtle change in a face expressing anger. Second, they did not show the same facilitation as healthy individuals when they needed 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 behavioral performance. High anxious individuals detected changes involving disgust or anger differently than control subjects, in within- as well as in between-category judgments, displaying a modulated categorical perception effect.

4. Experimental procedures

4.1. Participants

Twenty students 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 150 first year students from the University of Louvain. All participants were right-handed females, between the ages of 18 and 28 years, with normal/corrected vision and without neurological disease or depression.

We used a median split among STAI scores to create a standardized measure of anxiety (median: STAI-T = 50; STAI-S = 52) 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 two groups of ten participants: healthy control participants (HCP) and social anxious participants (SAP). Group characteristics are reported in Table 2.

t-tests showed no significant difference in age ($t(18) = -.214$, NS). *t*-tests found that SAP showed significantly greater anxious trait scores ($t(18) = -6.936$, $p < 0.001$) and state scores ($t(18) = -8.376$, $p < 0.001$) than HCP. SAP also presented significantly more social anxiety ($t(18) = -5.522$, $p < 0.001$). Subjects equally differed on Beck Score ($t(18) = -6.143$, $p < 0.001$), but mean scores of the two groups remain lower than the clinical level of depression (defined by a cut-off score of 10 on the 13-item Beck Inventory Scale, see Furlanetto et al., 2005), operationally confirming that participants did not exhibit depression.

Table 2 – Mean characteristics of the samples (SD in parentheses)

	Socially anxious participants	Healthy control participants
Age	20.60 (2.22)	20.40 (1.95)
Beck Score [a]	6.5 (1.84)	2.2 (1.2)
STAI-E [a]	59.20 (4.42)	43.10 (4.17)
STAI-T [a]	60.50 (7.57)	41.95 (3.76)
FNE [a]	21.00 (6.48)	8.2 (3.43)

[a] Mean differences between conditions ($p < 0.001$).

4.2. Stimuli

Faces of two actors (A, B), each portraying anger and disgust, were taken from Beaupré and 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 a description of the morphing procedure). Stimuli were prepared by blending two faces in the following proportions: 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 respective continuum (i.e., AAD 5% refers to actor A, continuum anger to disgust, 5% 'A disgust' and 95% 'A anger") (see Fig. 5).

Results from a pretest of 20 participants showed that AAD 5% and BAD 5% were identified as angry faces, whereas AAD 95% and BAD 95% were perceived as disgusted faces. Moreover, AAD 35% and BAD 35% were predominantly identified as angry, and AAD 65% and BAD 65% were identified as disgusted. Based on these stimuli, four conditions using separate triads of stimuli were generated for the oddball paradigm. For instance, the condition AAD 5%–35%–65%, where AAD 35% constituted the frequent stimulus perceived as anger, and AAD 5% and 65% where the deviant stimuli, respectively, was 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 conditions 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). Using this method, the physical difference on the continuum separating the stimuli (30%) was constant across all trials.

Stimuli, sizing 6 cm horizontal and 8 cm vertical and subtending a visual angle of 3×4°, were presented during 500 ms, one at a time, on a black background. A black screen was displayed as the intertrial interval, lasting randomly between 1300 and 1600 ms. Sixteen blocks were created, each containing 100 stimuli (80 frequent stimuli (e.g. face AAD 35%) and 20 deviant stimuli (e.g. 10 face AAD 5%, and 10 face AAD 65%)). The order of the sixteen blocks was counterbalanced between participants.

Fig. 5 – Illustrations of the morphed faces used in the experiment for the continua 'A anger to disgust' and 'B anger to disgust'.

4.3. *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 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. Data were filtered with a 30 Hz low-pass filter.

4.4. *Procedure*

The experiment took place between 1 and 2 weeks after the pre-selection of participants. During the ERPs recording, participants sat on a chair in a dark room with head placement of 1 m from the screen and restrained by a chin rest. The participants were asked to identify, as quickly as possible, deviant stimuli by pressing a mouse button with their right index finger. They were given 1500 ms to respond from stimulation onset. The entire experiment took approximately 50 min.

4.5. *Data analysis*

Two parameters were coded for every condition: (1) type of stimulus (rare BETWEEN DISGUST; rare WITHIN ANGER; rare BETWEEN ANGER; rare WITHIN DISGUST; using only the frequent stimuli preceding the deviant ones in order to have the same number of averaged frequent stimuli); and (2) response type (keypress for deviant stimuli, no keypress for frequent stimuli). This coding allowed us to compute different averages of ERP target stimuli. Averages were created for each participant individually. For N2b, P3a and P3b components, individual peak amplitudes and individual maximum peak latencies were obtained for the ERPs through subtracting the waveforms evoked by standard and deviant stimuli. Components were manually identified, peak-to-peak, on the basis of 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 analyzed the data using an ANOVA with type of deviant trials (BETWEEN or WITHIN) and emotion (anger or disgust) as within factors and anxiety group (i.e., HCP and SAP) as between factor. Greenhouse–Geisser corrections were applied to within-subject comparisons. Paired Student's *t*-tests were also used when appropriate. The alpha level of significance was set at 0.05 throughout analyses.

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