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The impact of the stimulus features and task instructions on facial processing in social anxiety: An ERP investigation

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ABSTRACT

Social anxiety has been characterized by an attentional bias towards threatening faces. Electrophysiological studies have demonstrated modulations of cognitive processing from 100 ms after stimulus presentation. However, the impact of the stimulus features and task instructions on facial processing remains unclear. Event-related potentials were recorded while high and low socially anxious individuals performed an adapted Stroop paradigm that included a colour-naming task with non-emotional stimuli, an emotion-naming task (the explicit task) and a colour-naming task (the implicit task) on happy, angry and neutral faces. Whereas the impact of task factors was examined by contrasting an explicit and an implicit emotional task, the effects of perceptual changes on facial processing were explored by including upright and inverted faces. The findings showed an enhanced P1 in social anxiety during the three tasks, without a moderating effect of the type of task or stimulus. These results suggest a global modulation of attentional processing in performance situations.

1. Introduction

Social anxiety disorder (SAD) has been characterized by an attentional bias towards emotional facial expressions (EFE, for a review see Staugaard, 2010). While behavioural studies have demonstrated a rapid orientation towards facial expressions (Klumpp and Amir, 2009; Mogg and Bradley, 2002; Mogg et al., 2004), neuroimaging studies have shown an increased amygdala response, exaggerated negative emotion reactivity, and reduced cognitive regulation-related neural activation in response to human faces in individuals with SAD (Ball et al., 2012; Goldin et al., 2009).

Due to its high temporal resolution, the event-related potentials (ERPs) technique has been used to examine the temporal dynamics of the processes involved in face perception. The influence of emotional facial features begins as early as the P1 component (Eimer et al., 2003; Vuilleumier and Pourtois, 2007), generated by the extrastriate visual areas in a perceptual stage of information processing (Allison et al., 1999). The P1 amplitude is larger for angry and fearful faces than neutral faces, suggesting enhanced sensory processing of EFE associated with a representation of threat (Batty and Taylor, 2003; Pizzagalli et al., 1999). The P1 is also sensitive to top-down attentional influences (Taylor, 2002; Taylor and Khan, 2000) and appears larger for attended than unattended stimuli (Hillyard et al., 1998). Numerous studies on facial processing in SAD showed P1 of higher amplitudes to schematic, artificial and natural facial stimuli regardless of expression (Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Rossignol et al., 2012b). For instance, Rossignol et al. (2012b) demonstrated the same P1 enhancement in sub-clinical SAD individuals for happy, angry, fearful, disgusted and neutral faces. Their results support the theory of hypervigilance to faces in individuals with SAD and the absence of a specific enhancement to threat in phobic patients (Eysenck, 1997; Kolassa et al., 2006). In contrast, other authors have argued that the increased sensitivity to faces is a specific feature of social anxiety (Ball et al., 2012) and may be specific to emotional expressions (McTeague et al., 2011). However, if this is true, several aspects remain unclear. First, the specificity of this amplification is still a matter of debate since both general and specific attentional biases have been documented (Schmitz et al., 2012). Second, the role of the experimental tasks needs to be clarified. As P1 is sensitive to task demands (Taylor, 2002), the attention may be directed towards the emotional features of a face to elicit enlarged P1. Conversely, P1 may be automatic and appear for all stimuli identified as faces, even when the emotion of the face has not been explicitly processed.

A second ERP component relevant when studying facial processing in individuals with SAD is the N170, a temporal–parietal

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negativity particularly sensitive to faces and associated with the structural encoding of facial features and configurations (Bentin et al., 1996; Eimer, 2000). The activation of the N170 in response to experimental manipulations such as face inversion tasks (see Eimer et al., 2011) is generally interpreted as a disruption of configural face processing in favour of analytic processing. The N170 presents a particular interest for exploring face processing in individuals with SAD, as this component provides information about the nature of face encoding. Several affective disorders affecting facial processing, such as schizophrenia or autism, disrupt the activation of the N170 (Campanella et al., 2006; Dawson et al., 2005). Similarly, two studies have reported larger right N170 amplitudes to angry faces when individuals with SAD had to explicitly process emotion (Kolassa and Miltner, 2006) and when anticipatory anxiety of public speaking was induced in healthy participants (Wieser et al., 2010). These modulations may indicate more analytical processing of different facial elements (eyes, mouth, etc.) in SAD. However, other studies have failed to replicate this effect (Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Rossignol et al., 2012a). Since the studies showing a moderating effect of SAD on the N170 required participants to explicitly process emotion, these inconsistencies may be a result of different task instructions (e.g. attended to emotion or not) (Mühlberger et al., 2009). Thus, additional research is needed to better understand how social anxiety may affect the configural encoding of social information and to clarify the role of task demands.

A third component that is of particular interest is the P2 that reflects sustained perceptual processing (Schupp et al., 2004) and the mobilization of attentional resources (Bar-Haim et al., 2005). P2 has been found to be larger for pleasant and unpleasant pictures (Carretié et al., 2004) and may be functionally associated with the evaluation of the emotional relevance of visual stimuli (Carretié et al., 2001; Dennis and Chen, 2007) and the complexity of emotional appraisal (Kolassa et al., 2009). Recently, Rossignol et al. (2012b) demonstrated a global enhancement of this component to faces irrespective of emotion in socially anxious individuals, suggesting a greater recruitment of attentional resources on emotionally significant stimuli in individuals with SAD. Conversely, van Peer et al. (2010) reported increased P2 amplitudes for angry faces compared to neutral and happy expressions in individuals with SAD, even in conditions of restricted awareness. Finally, other researchers have found no effect of SAD on the P2 (Kolassa et al., 2009; Kolassa and Miltner, 2006). As these studies used different tasks and stimuli, one may argue that the modulation of the P2 in socially anxious individuals may depend on these factors, and thus needs further investigation.

As the aforementioned studies demonstrate, SAD has been characterized by a hypersensitivity to facial expressions at different processing stages. However, there are inconsistencies in the effect of facial expressions on ERP modulation that might be due to the stimulus itself or the task completed. In the present study, participants suffering from high and low social anxiety performed a modified emotional Stroop task (Williams et al., 1996) adapted from the original Stroop task (Stroop, 1935). In this task, participants must name the colour of a word or a picture while ignoring the semantic or emotional content of the stimulus. Increased response latencies in colour-naming threatening compared to neutral stimuli are considered as an indication of an attentional bias. Numerous studies using this task have reported attentional biases in anxious states (see Bar-Haim et al., 2007 for a review). The typical interpretation of this emotional Stroop effect is that the more an individual attention is drawn to socially threatening stimuli, the less attentional resources will be left for colour naming. Several studies using emotional Stroop task demonstrated an attentional bias to socially threatening words in individuals with SAD (e.g., Amir et al., 2002; Maidenberg et al., 1996; Mattia et al., 1993).

As our objective was to better delineate the role of social anxiety on emotional processing in relation to task demands, we contrasted explicit processing of facial stimuli (emotion naming task – identify the EFE) and implicit processing of the same stimuli (colour naming task – identify the colour of a mask affixed on the face). The other aim of this study was to investigate the influence of the stimulus materiel itself on ERP correlates during facial processing. First, we addressed the question of an emotional specificity of ERP enhancement in individuals with SAD. For this purpose, we compared neural responses to neutral, happy and angry faces. We also included a control colour-naming task with non-emotional stimuli (i.e., rectangles) to compare the processing of emotional and non-emotional stimuli through emotional and non-emotional tasks. The current experimental design should allow us to better disentangle whether the ERP enhancement in individuals with SAD is limited to emotional faces (specificity hypothesis), generalized to neutral faces (hypothesis of hypervigilance to faces) or coloured rectangles (general hypervigilance hypothesis). Second, the effect of SAD on configural processing of facial information was studied through the inclusion of upright and inverted faces in each task.

Behavioural measures (i.e. response accuracy, reaction times) were combined with the assessment of early ERPs (i.e. P1, N170, P2). Based on the results of studies using an emotional Stroop (for a review see Bar-Haim et al., 2007), we expected interference in the colour naming task with facial stimuli, indexed by longer RT for all participants, with a stronger interference for angry EFE. This effect should be enhanced in individuals with SAD, as it was previously shown with threatening social words (e.g. Amir et al., 2002; Maidenberg et al., 1996; Mattia et al., 1993). For the emotion naming task, our expectation was to find faster response times to angry compared to neutral and happy faces, with even faster reactions in high socially anxious (HSA) than low socially anxious individuals (LSA). This hypothesis was based on the previous findings of preferential processing of threat-related emotional faces (e.g. Mogg and Bradley, 2002; Mogg et al., 2004). We also expected a general enhancement of the P1 to all faces regardless of emotion, indicating a hypervigilance for faces in general (e.g. Kolassa et al., 2009, 2007). As the SAD influence on the N170 may depend on the explicit nature of angry EFE processing (Kolassa and Miltner, 2006), we expected increased N170 modulations by in individuals with SAD only when explicitly processing angry facial stimuli. Furthermore, if SAD leads to altered configural encoding of facial stimuli, socially anxious participants should be less responsive to face inversion, observed through attenuated differences of N170 amplitudes between upright and inverted faces. Finally, it was hypothesized that P2 of higher amplitude would be observed in HSA group, reflecting the mobilization of attentional resources (Rossignol et al., 2012b; van Peer et al., 2010).

2. Method

2.1. Participants

Forty individuals with normal/corrected vision and without any neurological diseases (age range: 18–25; 24 right-handed) were preselected from a large sample of students at the University of Louvain based on their score on the Liebowitz Social Anxiety Scale (LSAS, Liebowitz, 1987). A score of 65 and above suggests the presence of moderate to very severe social phobia. Accordingly, high socially anxious (HSA) individuals ($N = 18$; 9 females) were defined as those scoring 65 or more on the LSAS while the low-anxiety (LSA) individuals ($N = 18$; 9 females) were those who scored under 55 (Yao et al., 1999). Participants also completed the 13-item Beck Depression Inventory (Beck and Beamesderfer, 1974) and the Trait Anxiety Inventory (STAI-T, Spielberger et al., 1983).

Group characteristics are reported in Table 1. Four participants had to be excluded because of artefact problems during ERP recording. Thus, our remaining sample was composed of thirty-six individuals. As expected, the two groups differed in the measures of social anxiety ($t(34) = 8.58$, $p < .001$) but no group differences were found for age ($t(34) = .36$, $p = .72$), depression ($t(34) = 1.39$, $p = .173$) or trait anxiety level ($t(34) = 1.36$, $p = .184$).

Table 1
Participants characteristics as a function of group assignment (standard deviations in parentheses).

	LSA participants (N = 18)	HSA participants (N = 18)
Age	20.1 (1.9)	19.89 (1.2)
LSAS	35.8 (14.9)	76.2 (13.4)
STAI-T	54.6 (3.7)	56.3 (3.63)
Beck	3.5 (2.7)	5.7 (6.0)

Note. LSAS is Liebowitz Social Anxiety Scale; STAI-T is Spielberger Anxiety Inventory-Trait; The Beck is the 13-items Beck Depression Inventory

2.2. Stimuli

The experimental task used photographs of 12 different actors (6 women, 6 men) depicting 3 emotional expressions (neutral, happy, angry) taken from the Karolinska Directed Emotional Faces (KDEF, Lundqvist and Flykt, 1998). All faces were cropped to remove external features (4 cm wide by 5.6 cm high, degrees of the visual angle = 3° × 4°). An inverted version of each face was also used. Half of the stimulus set was used in the facial expression-naming task (3 men) whereas the other half was superimposed with a red, green or blue mask for the colour-naming task with facial stimuli. In the control colour-naming task with non-emotional stimuli, 40 red, blue and green-coloured rectangles were presented, each measuring 5.60 cm horizontal and 3.97 cm vertical on a black background (see Fig. 1 for a sample of the faces used in the tasks).

2.3. Emotional Stroop paradigm

The experimental design followed a modified version of the emotional Stroop paradigm (MacLeod, 2001; Williams et al., 1996). Participants successively performed the colour-naming task with non-emotional stimuli, the facial expression-naming task (i.e. explicit task) and the colour-naming task with facial stimuli (i.e. implicit task).

First, the colour-naming task with non-emotional stimuli consisted of two blocks of 120 stimuli each (40 rectangles of each colour category). The inclusion of the control colour-naming task offers the possibility to explore the hypothesis of specific modulations of social stimuli processing vs. a more general pattern involving other kinds of visual information in individuals with SAD.

Second, the facial expression-naming task comprised 6 experimental conditions (=3 emotions × 2 orientations) and 36 stimuli (=6 actors × 3 emotions × 2 orientations). Participants performed a total of 6 blocks each composed of 60 stimuli (3 emotions × 2 orientations × 10 repetitions). Thus, in total, the facial expression-naming task consisted of 360 stimuli (120 per emotion category).

Finally, the colour-naming task with facial stimuli contained 18 experimental conditions (=3 emotions × 2 orientations × 3 colours). Each type of stimulus (36 stimuli = 6 actors × 3 emotions × 2 orientations) was repeated 10 times, so that the entire task comprised of 360 stimuli with 120 per colour category. The task was divided into six blocks, in each block 60 stimuli were presented.

In the all tasks, faces or rectangles were presented in a randomized order and the order of the blocks as well as the sequence of response buttons were counterbalanced across participants. Each trial started with a fixation cross composed of a white 4 cm × 6 cm 2-pixel thick "plus sign" in the centre of an outline frame, presented for 400 ms. Stimuli were then presented one by one for 800 ms with a black screen displayed as an inter-trial interval lasting 500 ms. Participants were instructed to identify as quickly as possible the emotional expression in the explicit task and the colour of the mask in the control task and the implicit task by pressing the correct response button of a joystick amongst 3 possible choices.

2.4. EEG recording and ERP recording

During the ERP recording, subjects sat in a chair in a dark room with their head placed 100 cm from the screen and restrained in a chin rest. All stimuli were presented on a dark screen background of a Dell Insperon 17R computer via Eeprobe program. The electroencephalogram (EEG) recordings were performed with 32 electrodes mounted in an electrode Quick-Cap with the standard 10–20 International System and intermediate orientations. Recordings were measured with a linked mastoid physical reference but were re-referenced 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 20 kΩ. EEG was continuously recorded (sampling rate 512 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 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. Epochs beginning 100 ms prior to stimulus onset and continuing for 600 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. After inspection of grand averages and individual sets of data, ERP mean amplitudes were computed for: (a) the P1 component, isolated within the 100–170 ms post-stimulus temporal window on Oz electrode, (b) the N170, peaking between a 170 and 220 ms post-stimulus windows on lateral parietal electrodes (P7 and P8), and (c) the P2, recording between 200 and 280 ms on Oz.

2.5. Data analysis

Statistical analyses were computed using Statistical Package for Social Sciences, 17th version (SPSS 17.0). For behavioural data, trials with errors were eliminated from analyses and reaction times deviating more than 3 SDs were excluded as outliers. *First*, independent sample t-tests with Group (HSA, LSA) as between subject factors were applied on response times, correct responses, P1, N170 and P2 mean amplitudes recorded during the control colour naming task. *Second*, behavioural data, P1 and P2 mean amplitudes recorded during the Stroop paradigm were analysed with 2 × 2 × 3 × 2 repeated measured analyses of variance (ANOVAs) with Task (colour-naming task – implicit task – vs. emotion-naming task – explicit

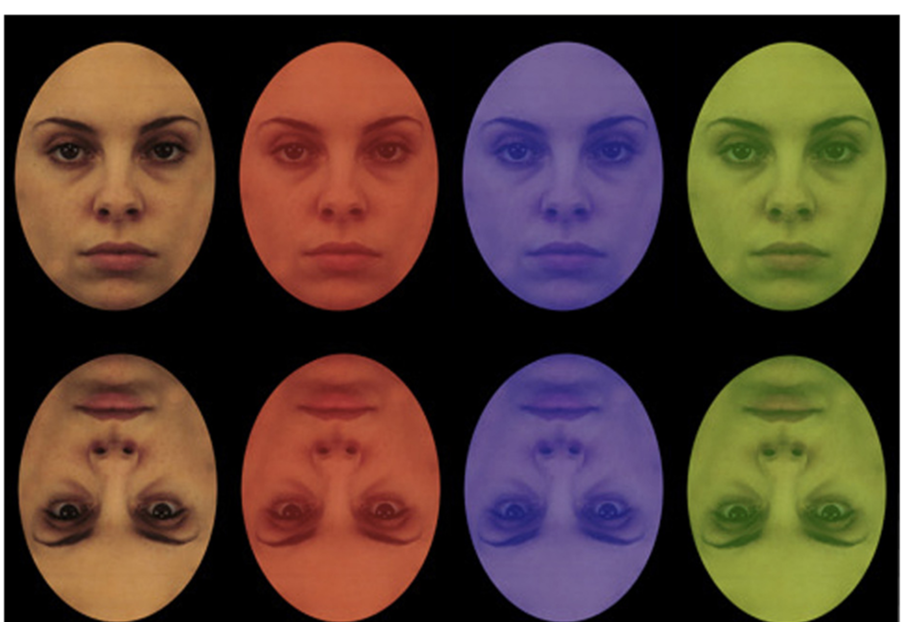

Fig. 1. Illustration of a sample of the faces used in the tasks. (For interpretation of the references to colour in the text, the reader is referred to the web version of this article.)

task), Orientation (upright vs. inverted) and Emotion (angry vs. happy vs. neutral) as within-subject factor, and Group (HSA participants vs. LSA participants) as a between-subjects factor. The analysis of N170 mean amplitudes included the site of recording (P7 vs. P8) as a within factor. Artefact-free trial counts for ERP analyses ranged on average from 47.8 to 55.3 per conditions in the emotion and colour-naming task and from 220 to 226 in the colour-naming task with non-emotional stimuli, and did not significantly differ across groups.

The reported *p*-levels of all the other ANOVAs were corrected for violations of the sphericity assumption using the Greenhouse–Geisser (1959) epsilon correction. Simple effects were explored throughout, and a Bonferroni correction for multiple comparisons was applied to all the *t*-tests. The alpha level of significance was set at 0.05 throughout.

3. Results

3.1. Control colour-naming task

3.1.1. Behavioural data

A main effect of Group ($t(34) = 2.08$, $p = .045$) on response times showed faster responses in HSA participants compared to LSA participants. However, response accuracy ($t(34) = 1.32$, $p = .195$) did not differ between groups.

3.1.2. ERP data

A main effect of Group ($t(34) = 2.79$, $p = .009$) revealed larger P1 in HSA as compared to LSA participants. In contrast, both N170 ($t(34) = .63$, $p = .53$) and P2 amplitudes ($t(34) = 1.01$, $p = .32$) did not differ between groups.

3.2. Stroop paradigm

3.2.1. Response accuracy

Our ANOVA showed a main effect of Task ($F(1,34) = 45.74$, $p = .001$, $\eta^2_p = .57$), revealing better performance for the colour-naming task than for the emotion-naming task. Second, a main effect of Emotion ($F(2,68) = 3.18$, $p = .048$, $\eta^2_p = .08$) showed that participants were more accurate for happy faces than for neutral ($t(35) = 2.16$, $p = .037$), without a significant difference between neutral and angry faces ($t(35) = 1.25$, $p = .22$), nor between happy and angry faces ($t(35) = 1.25$, $p = .22$). Third, a significant interaction between Emotion and Task emerged ($F(2,68) = 7.51$, $p = .003$, $\eta^2_p = .18$). To follow-up this interaction, we computed separate analyses for each task. The results indicated a significant effect of Emotion in the emotion-naming task ($F(2,68) = 5.49$, $p = .013$, $\eta^2_p = .14$) and in the colour-naming task ($F(2,68) = 3.71$, $p = .030$, $\eta^2_p = .10$). For the emotion-naming task, neutral faces decreased performance compared to angry ($t(35) = 2.68$, $p = .011$) and happy ones ($t(35) = 2.55$, $p = .015$), with no difference between angry and happy faces ($t(35) = .85$, $p = .40$). For the colour-naming task, participants were more accurate for neutral faces compared to angry ones ($t(35) = 2.72$, $p = .010$), with no difference between neutral and happy faces ($t(35) = .48$, $p = .64$), and no differences appeared between angry and happy faces ($t(35) = 1.86$, $p = .071$). Our analysis, however, found no effect of Orientation ($F(1,34) = .20$, $p = .66$) or an interaction with the Task ($F(1,34) = .12$, $p = .73$) and no effect of Group on response accuracy ($F(1,34) = .17$, $p = .684$) or interaction with Group. To conclude, participants correctly named the colour of rectangles better than the colour of faces. The analysis revealed that happy faces improved performance, but the task instructions modulated this effect. In the colour-naming task, happy and angry faces led to better identification than neutral faces, whereas the neutral faces lead to better performance than to angry faces in the emotion-naming task.

3.2.2. Response times

Our analysis demonstrated a main effect of Task ($F(1,34) = 291.82$, $p < .001$, $\eta^2_p = .90$). That is, participants identified the colour of a face faster than the emotional expression. Second, a main effect of Emotion ($F(2,68) = 8.25$, $p = .001$, $\eta^2_p = .20$) showed faster responses to happy faces compared to neutral ($t(35) = 3.84$, $p < .001$) and angry EFE ($t(35) = 4.18$, $p < .001$). Although we found no main effect of Orientation ($F(1,34) = 2.07$, $p = .160$), the analysis revealed a significant interaction between Emotion, Task and Orientation ($F(2,68) = 3.52$, $p = .035$, $\eta^2_p = .09$). Subsequent analyses found a significant two-way interaction between Emotion and Orientation for the emotion-naming task ($F(2,68) = 5.21$, $p = .008$, $\eta^2_p = .13$) but not for the colour-naming task ($F(2,68) = 2.47$, $p = .092$). In the emotion-naming task, a significant effect of Orientation was observed for angry ($F(1,34) = 4.40$, $p = .043$, $\eta^2_p = .11$) and happy facial expressions ($F(1,34) = 7.90$, $p = .008$, $\eta^2_p = .19$), but not for neutral faces ($F(1,34) = 1.03$, $p = .317$). These data indicate that inverted faces slowed down emotion-naming processing for angry faces ($t(35) = 2.13$, $p = .040$) but accelerated the identification of happy faces ($t(35) = 2.82$, $p = .008$). Group membership did not influence response latencies ($F(1,34) = 3.41$, $p = .073$) and did not interact with the other factors. In summary, participants identified the colour of a face faster than the facial expression. Individuals also identified happy faces faster than neutral and angry faces. Finally, the inversion of the faces delayed participant's responses for angry faces but accelerated their reaction times for happy faces. Behavioural data are presented in Fig. 2 and Table 2.

3.2.3. P1 mean amplitude

Our analysis revealed a main effect of Group ($F(1,34) = 4.39$, $p = .044$, $\eta^2_p = .11$), indicating that HSA participants (5.33 μV) exhibited larger P1 amplitude for all faces than LSA participants (3.80 μV) (see Fig. 3). Second, a main effect of Orientation ($F(1,34) = 10.53$, $p = .003$, $\eta^2_p = .24$) reflected higher P1 waves for inverted faces (4.61 μV) than for upright faces (4.10 μV). However, the Orientation effect was moderated by a significant interaction between Task and Orientation ($F(1,34) = 4.59$, $p = .039$, $\eta^2_p = .12$), with the inversion effect appearing in the explicit task ($F(2,68) = 19.85$, $p < .001$, $\eta^2_p = .369$) but not in the implicit task ($F(1,34) = 1.08$, $p = .306$). An interaction among Task, Orientation and Emotion ($F(2,68) = 3.21$, $p = .047$, $\eta^2_p = .08$) was observed but the subsequent analyses failed to reach significance. Moreover, the analysis did not show a main effect of Task ($F(1,34) = .93$, $p = .342$) and Emotion ($F(2,68) = 1.03$, $p = .362$). Finally, Group did not interact with any other factor. In sum, SAD was associated with a global amplification of P1 to all faces. In addition, P1 was also increased by inversion but this effect only occurred in the explicit task.

3.2.4. N170 mean amplitude

First, our analysis revealed the expected effect of Orientation ($F(1,34) = 5.64$, $p = .023$, $\eta^2_p = .14$): inverted faces evoked higher N170 (−2.27 μV) than upright faces (−1.74 μV). Importantly, an interaction between Orientation and Task moderated this main effect ($F(1,34) = 13.13$, $p = .001$, $\eta^2_p = .28$). Face orientation influenced cognitive processes when facial expression was the focus of attention ($F(1,34) = 15.10$, $p < .001$, $\eta^2_p = .31$) but not in the colour-naming task ($F(1,34) = .03$, $p = .870$). Furthermore, a three-way interaction between Orientation × Task × Site of recording ($F(1,34) = 4.57$, $p = .040$, $\eta^2_p = .12$) and a four-way interaction of face Orientation × Task × Sites of recording × Emotion was observed ($F(2,68) = 3.67$, $p = .031$, $\eta^2_p = .10$). When analyzing the four-way interaction, separated analyses for each task indicated a significant interaction of Inversion × Emotion × Sites in the colour-naming task ($F(2,68) = 4.78$, $p = .012$, $\eta^2_p = .12$) but not in the emotion-naming task ($F(2,68) = .12$, $p = .888$). Complementary analyses were performed and showed a significant interaction of Emotion × Site of recording for inverted ($F(2,68) = 4.48$, $p = .015$, $\eta^2_p = .12$) but not upright faces ($F(2,68) = 1.55$, $p = .22$). However, further analysis

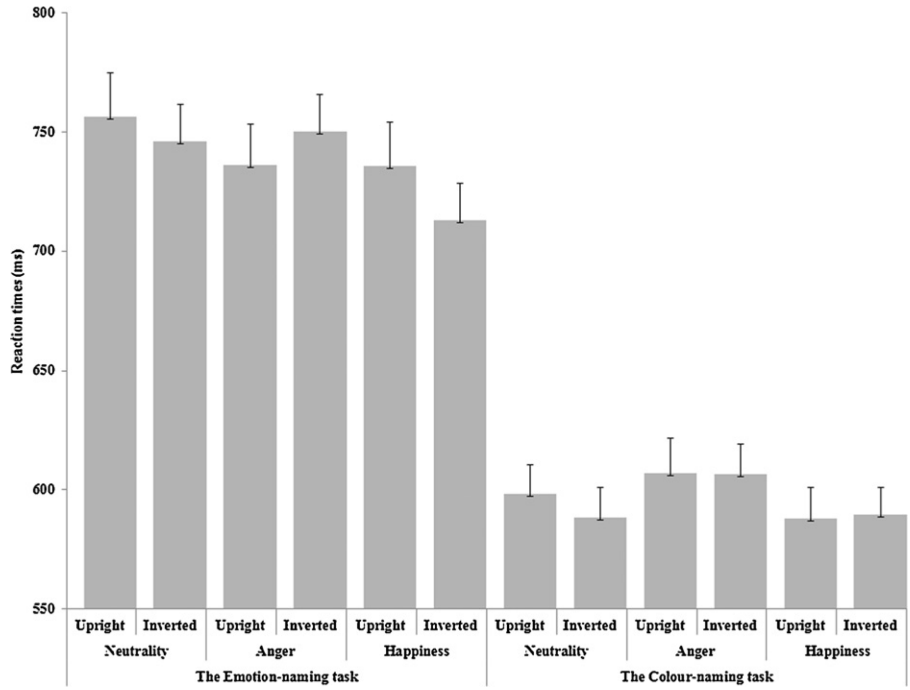

Fig. 2. Mean response times (RT, in ms) as a function of Task and Stimulus. Errors bars represent standard error of the mean.

failed to find a main effect of Emotion on the right site of recording ($F(2,68) = 3.05$, $p = .054$, $\eta_p^2 = .08$) and on the left site ($F(2,68) = .24$, $p = .789$). The analysis did not demonstrate a main effect of Emotion ($F(2,68) = .26$, $p = .773$), Task ($F(1,34) = 2.23$, $p = .145$) or Group ($F(1,34) = .27$, $p = .610$). Finally, no other interactions involving group or others factors reached significance. In sum, the present finding showed higher amplitudes of N170 to inverted faces but this effect occurred only when the emotion was explicitly processed.

Table 2
Mean response times (RT, in ms) and percentage accuracy (CR, in %) in each Task for Low Socially Anxious Participants and High Socially Anxious Participants (standard deviations are presented between brackets).

Control colour-naming	RT (ms)					
Stroop task	LSA		HSA		Mean	
	590.5 (65.2)		546.1 (63.0)		568.3 (67.1)	
	Explicit	Implicit	Explicit	Implicit	Explicit	Implicit
Upright angry faces	770.6 (98.9)	621.3 (80.3)	702.0 (103.7)	592.7 (97.0)	736.3 (105.7)	607.0 (88.9)
Inverted angry faces	783.0 (91.0)	627.1 (78.7)	717.2 (94.8)	586.1 (73.3)	750.1 (97.4)	606.6 (77.8)
Upright happy faces	762.8 (101.4)	614.3 (87.0)	708.4 (121.3)	561.7 (67.8)	735.6 (113.6)	588.0 (81.3)
Inverted happy faces	747.5 (97.2)	607.5 (66.7)	678.3 (90.2)	571.3 (69.7)	712.9 (98.9)	589.4 (69.7)
Upright neutral faces	775.5 (108.9)	624.5 (83.3)	737.1 (110.9)	571.7 (65.9)	756.3 (110.1)	598.1 (77.7)
Inverted neutral faces	767.2 (98.2)	610.1 (98.2)	725.2 (86.1)	566.7 (71.6)	746.2 (93.5)	588.4 (76.0)
Control colour-naming	CR (%)					
Stroop task	95.2 (2.6)		94.12 (2.5)		94.7 (2.6)	
	Explicit	Implicit	Explicit	Implicit	Explicit	Implicit
Upright angry faces	90.3 (6.6)	93.2 (4.2)	88.1 (7.9)	92.0 (4.7)	89.2 (7.3)	92.6 (4.4)
Inverted angry faces	86.2 (8.3)	93.2 (4.0)	88.9 (6.5)	92.8 (4.4)	87.6 (7.5)	93.0 (4.2)
Upright happy faces	89.8 (5.8)	94.3 (3.6)	88.4 (6.1)	94.5 (5.0)	89.1 (5.9)	94.4 (4.3)
Inverted happy faces	88.7 (5.8)	94.0 (3.8)	89.5 (8.3)	92.9 (4.2)	89.1 (7.9)	93.5 (4.0)
Upright neutral faces	85.5 (11.6)	94.5 (2.7)	85.3 (10.1)	93.4 (3.6)	85.4 (10.8)	93.9 (3.2)
Inverted neutral faces	87.2 (8.6)	94.5 (3.4)	84.8 (8.4)	94.1 (2.8)	86.0 (8.4)	94.3 (3.1)

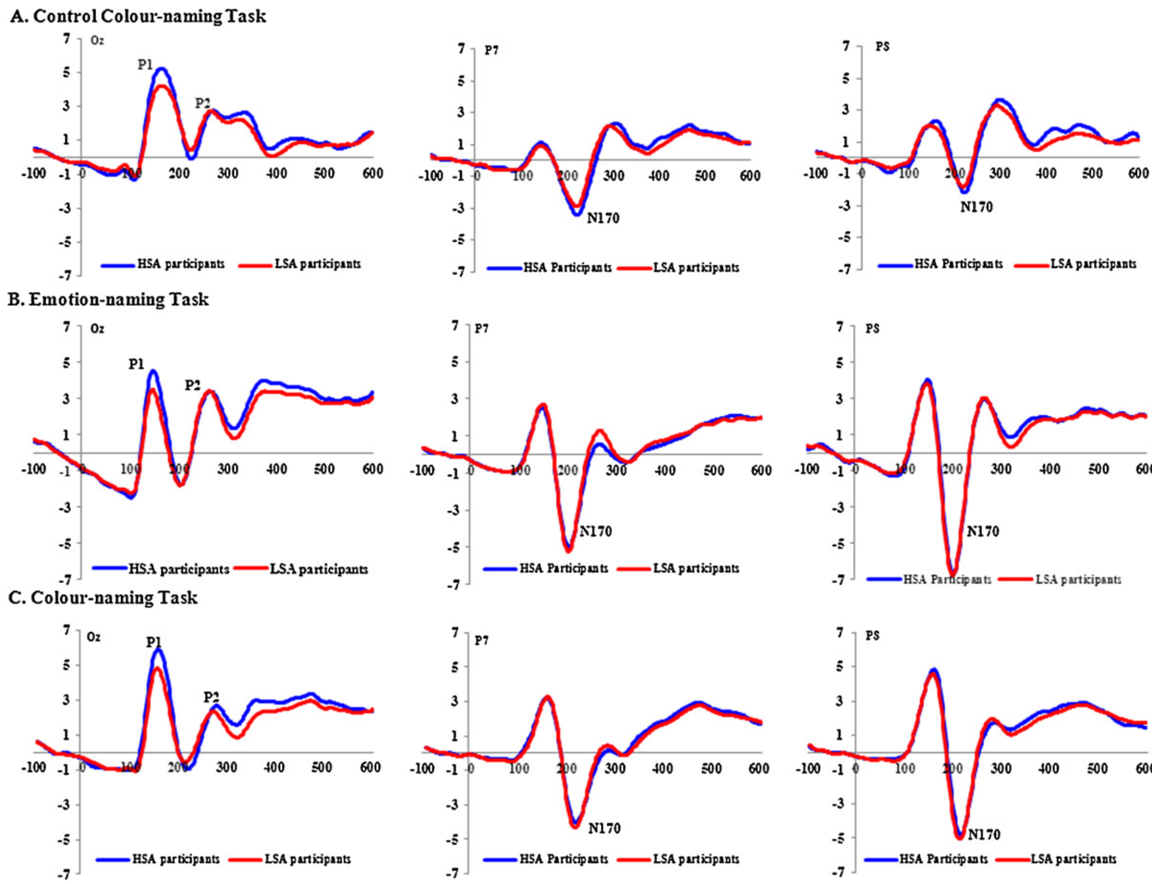

Fig. 3. Grand mean ERPs between HSA and LSA Group for the control colour-naming task (A), the emotion-naming task (B) and the colour-naming task (C) at electrode Oz with time windows of P1 and P2 and at electrodes P7 and P8 with time window of N170.

3.2.5. P2 mean amplitude

A main effect of Task was observed ($F(1,34) = 64.43$, $p < .001$, $\eta^2_p = .65$). The emotion-naming task induced larger P2 mean amplitudes (4.86 μV) than the colour-naming task (2.11 μV). The analysis did not reveal any evidence for a main effect of Emotion ($F(2,68) = .57$, $p = .559$), Orientation ($F(1,34) = .20$, $p = .658$) or Group ($F(1,34) = .47$, $p = .499$). No interactions involving group or others factors reached significance. ERP data are shown in Figs. 3 and 4.

4. Discussion

The present study aimed to examine the role of social anxiety and the respective influences of stimulus and task factors on ERP components when processing EFE. To disentangle these processes, we used an adapted version of the Stroop paradigm in which participants were successively presented a colour-naming task on non-emotional stimuli, an emotion-naming task (i.e. the explicit task) and a colour-naming task on emotional faces (i.e. the implicit task). Whereas the impact of task factors was examined by contrasting an explicit and an implicit EFE processing task, the effects of perceptual changes on facial processing were explored by including upright and inverted faces and the question of the specificity of attentional biases was addressed by using a control colour-naming task on non-emotional stimuli.

Our results demonstrated, first, that socially anxious participants were faster than non-anxious participants to identify the colour of neutral rectangles, but behavioural performance was not significantly modulated by social anxiety in tasks involving EFE. We did not evidence an emotional Stroop interference when high socially anxious participants were asked to identify the colour of angry faces, in contrast to previous behavioural studies using threat words (e.g. Maidenberg et al., 1996; Mattia et al., 1993). However, several studies using emotional Stroop tasks with faces did not demonstrate emotional interference when socially anxious samples had to process angry faces (Kolassa et al., 2007, 2006; van Peer et al., 2010).

Second, and importantly, we found a generalized amplification of early visual P1 in HSA individuals, for all stimuli and in all tasks, including the control task on simple coloured rectangles. The generalization of P1 enhancement to these neutral stimuli suggests that this phenomenon is not specific to faces, as is often postulated. As outlined by Bruhl et al. (2011), research on emotional processing in individuals with SAD has, for a long time, been guided by the specificity hypothesis which argues that neurobiological differences between phobic and non-phobic individuals are elicited only by stimuli activating the prepared-fear module. Consequently, most researchers exploring emotional processing in social anxiety used facial stimuli, as faces are social cues conveying important information about interpersonal evaluation. In that context, studies comparing positive, neutral and threatening facial cues expressions often showed a preferential attention towards threat. Recent data, however, suggests that the attentional bias towards facial expressions in individuals with SAD also includes positive emotions as shown by early sustained amplitude enhancement in response to fearful, angry and happy faces as compared to neutral faces (McTeague et al., 2011). Moreover, the anticipation of emotional pictures without social content may also have elicited an enhanced activity in brain regions associated with perception, attention and emotional arousal processing, suggesting a general disturbance of early attention processing (Bruhl et al., 2011). To

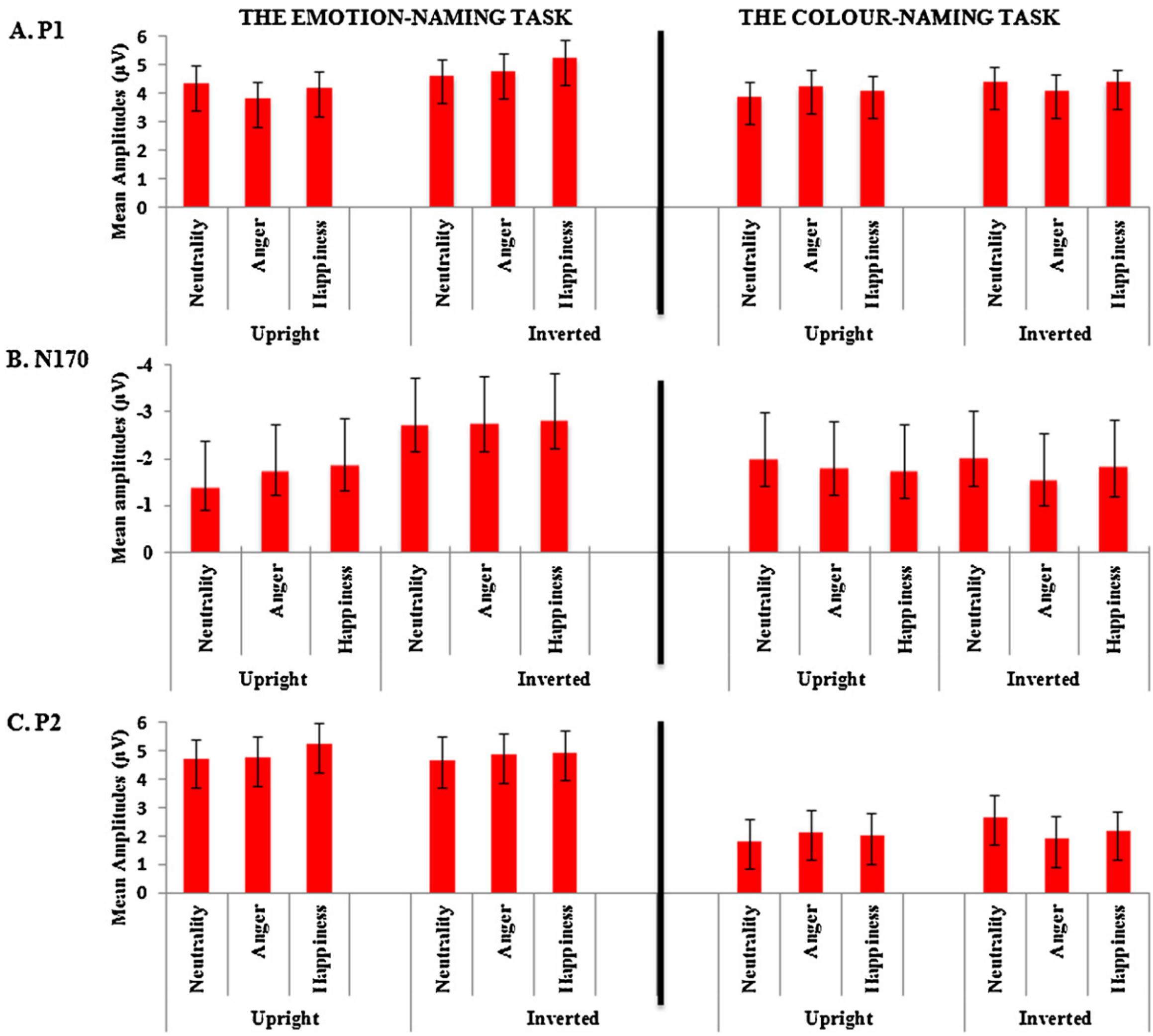

Fig. 4. Mean amplitudes and errors bars for P1 (A), N170 (B), and P2 (C) for each Emotion and Orientation.

the best of our knowledge, our study is the first to directly compare the cognitive processing of faces and basic visual stimuli using ERP. Our results demonstrate a general enhancement of perceptual processes regardless of the emotional or social nature of the stimulus. Besides the enhanced visual processing of simple coloured rectangles, we found that the enhanced perceptual responses to faces were not modulated by the task, the stimulus or its emotional load. However, it is possible that HSA participants are more motivated not to fail in performance situations than LSA participants. This may reflect a motivational influence that was independent of the task's instructions.

In contrast, social anxiety did not influence the activity of the N170. As the N170 is sensitive to the configural process of faces and appears to be reduced when a more analytic process is induced (notably by the inversion of the stimuli – see Eimer et al., 2003), a disturbed face representation in SAD should alter the pattern of N170 response. Moreover, if social anxiety leads to more analytical processing of different facial elements (eyes, mouth, etc.), these participants should have been less sensitive to inversion. For instance, SAD has been associated with avoidance of eye contact. As one hypothesis (Itier et al., 2007) proposed that the N170 is generated in eye-sensitive regions, one may hypothesize that this manipulation would lead to a less pronounced face inversion effect in SAD. The lack of an inversion effect in connection with social anxiety confirms that the configural processing of human faces may take place normally in sub-clinical SAD individuals, as suggested by the absence of social anxiety effect on the N170 in response to upright faces. If several studies did not observe SAD influence on the N170 (Kolassa et al., 2009, 2007; Mühlberger et al., 2009; Rossignol et al., 2012a), Kolassa and Miltner (2006) have reported enhanced right N170 amplitude in response to angry faces in socially phobic individuals. We first hypothesized that facial processing must be explicit to interact with social anxiety in facial structural encoding but our results failed to support this hypothesis. Consequently, we may conclude that individuals reporting social anxiety at a subclinical level are unlikely to suffer from altered configural processing of facial expressions, that impairment being characteristic of clinical levels of heavier social phobia. Yet, eye-tracking studies have highlighted disturbed facial processing in SAD. Some data call forth a vigilance/avoidance process (Wieser et al., 2009), while others outline a hyperscanning of faces associated with reduced foveal fixations of the eyes, that is particularly evident for angry faces (Horley et al., 2004) and an avoidance of facial features with an extensive scanning of non-facial features (Horley et al., 2003). As a consequence, we suggest that the N170 does not reflect the same level of visual processing as those demonstrated by the eye-tracking literature. Our results are in line with the hypothesis of a non-altered structural analysis of faces in individuals with SAD. Still, it might to be superseded by hyperscanning of faces after some hundreds milliseconds of presentation and finally an avoidance in the time interval from 1 to 1.5 s after face presentation (Wieser et al., 2009).

Finally, the P2 component is thought to reflect sustained perceptual processing (Schupp et al., 2003, 2004) and the mobilization of attentional resources (Bar-Haim et al., 2005). If some studies did not demonstrate an influence of SAD on P2 (Kolassa and Miltner, 2006), other results reported increased P2 amplitudes for angry faces compared to neutral or happy expressions (van Peer et al., 2010) or for both emotional and neutral faces (Rossignol et al., 2012b). Nevertheless, the present results did not evidence greater mobilization of attentional resources by faces in individuals with SAD, which is in accordance with Kolassa and Miltner (2006).

Independent of social anxiety, our results also show heightened amplitude of the P1 to inverted faces which is in line with previous research (Boutsen et al., 2006; Itier and Taylor, 2002, 2004), but only in the explicit task. The N170 also has larger amplitudes for inverted faces (e.g. Bentin et al., 1996; Itier and Taylor, 2004; Linkenkaer-Hansen et al., 1998; Rossion et al., 1999) during explicit facial processing exclusively. Our results indicate that the configural processing of visual information is influenced by the experimental task, since the N170 was not modulated by face inversion in the implicit facial processing task. Futhermore, enhanced P2 amplitudes were found only for facial stimuli in the explicit task. Higher P2 amplitudes have been used to index the extent to which individuals are captured by the stimuli emotionally (Rossignol et al., 2012b), but that component may also be sensitive to the complexity of emotional appraisal (Kolassa et al., 2007). Our findings show that the stimuli are not responsible for the enhancement of the P2 because, in that case, we would have outlined comparable P2 in both tasks. In contrast, the P2 enhancement was only apparent when the emotional content of the EFE was processed. One may also argue that such an explicit processing allows appraisal of the emotional relevance of the stimuli, which would be impossible in the implicit task. Thus, our results demonstrate the importance of the instructions provided to the participants in the modulation of their cognitive processing of stimuli.

If our results provide interesting clues about explicit and implicit processing of non-emotional and emotional stimuli in social anxiety, the present study is not without limitations. Mainly, this study involved a relatively small sample of sub-clinical socially anxious participants. Future studies need to be conducted with samples derived from clinical settings to determine whether the current findings generalize to clinical populations. Moreover, the low socially anxious group is particularly anxious, suggesting that the generalization of our results is perhaps limited to individuals with a general tendency to respond with state anxiety in threatening situations. Finally, our aim was to focus on early attentional processes indexed by earlier ERPs but some other components could have been relevant to measure, as for instance the early posterior negativity (EPN) or the late positive potential (LPP). These components have been shown as modulated by the stimuli's emotional load in several reports (Lee and Park, 2011) but the impact of social anxiety on their parameters remain unclear (for a review, see Staugaard, 2010) and should be investigated in further studies.

To conclude, this study shows that sub-clinical social anxiety may lead to early attentional vigilance without the supplemental influences of stimulus or task factors. More precisely, our results demonstrate an enhanced P1 in high socially anxious participants for all faces, irrespective of the displayed emotion. In addition, our findings suggest that this enhancement is not specific to faces but generalizes to simple coloured rectangles. Hence, our results do not support the theories which state that socially anxious individuals have a specific cognitive bias for facial stimuli. Rather, they suggest a global modulation of attentional processing in performance situations. In contrast, there was no evidence that social anxiety influences the amplitudes of N170 and P2 components.

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References

Allison, T., Puce, A., Spencer, D.D., McCarthy, G., 1999. Electrophysiological studies of human face perception. I. Potentials generated in occipitotemporal cortex by face and non-face stimuli. Cerebral Cortex 9 (5), 415–430, http://dx.doi.org/10.1093/cercor/9.5.415.

Amir, N., Freshman, M., Foa, E., 2002. Enhanced Stroop interference for threat in social phobia. Journal of Anxiety Disorders 16 (1), 1–9, http://dx.doi.org/10.1016/s0887-6185(01)00084-6.

Ball, T.M., Sullivan, S., Flagan, T., Hitchcock, C.A., Simmons, A., Paulus, M.P., Stein, M.B., 2012. Selective effects of social anxiety, anxiety sensitivity, and negative affectivity on the neural bases of emotional face processing. NeuroImage 59 (2), 1879–1887, http://dx.doi.org/10.1016/j.neuroimage.2011.08.074 (Research Support, N.I.H. Extramural).

Bar-Haim, Y., Lamy, D., Glickman, S., 2005. Attentional bias in anxiety: a behavioral and ERP study. Brain and Cognition 59 (1), 11–22, http://dx.doi.org/10.1016/j.bandc.2005.03.005.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M.J., Van Ijzendoorn, M.H., 2007. Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. Psychological Bulletin 133 (1), 1–24, http://dx.doi.org/10.1037/0033-2909.133.1.1.

Batty, M., Taylor, M.J., 2003. Early processing of the six basic facial emotional expressions. Cognitive Brain Research 17 (3), 613–620, http://dx.doi.org/10.1016/s0926-6410(03)00174-5.

Beck, A.T., Beamesderfer, A., 1974. Assessment of depression: the depression inventory. Modern Problems of Pharmacopsychiatry 7, 151–169 (comparative study).

Bentin, S., Allison, T., Puce, A., Perez, E., McCarthy, G., 1996. Electrophysiological studies of face perception in humans. Journal of Cognitive Neuroscience 8 (6), 551–565, http://dx.doi.org/10.1162/jocn.1996.8.6.551.

Bertrand, O., Perrin, F., Pernier, J., 1985. A theoretical justification of the average reference in topographic evoked potential studies. Electroencephalography and Clinical Neurophysiology 62 (6), 462–464.

Boutsen, L., Humphreys, G.W., Praamstra, P., Warbrick, T., 2006. Comparing neural correlates of configural processing in faces and objects: an ERP study of the Thatcher illusion. NeuroImage 32 (1), 352–367, http://dx.doi.org/10.1016/j.neuroimage.2006.03.023 (Research Support, Non-U.S. Gov't).

Bruhl, A.B., Rufer, M., Delsignore, A., Kaffenberger, T., Jancke, L., Herwig, U., 2011. Neural correlates of altered general emotion processing in social anxiety disorder. Brain Research 1378, 72–83, http://dx.doi.org/10.1016/j.brainres.2010.12.084.

Campanella, S., Montedoro, C., Streel, E., Verbanck, P., Rosier, V., 2006. Early visual components (P100, N170) are disrupted in chronic schizophrenic patients: an event-related potentials study. Neurophysiologie Clinique 36 (2), 71–78, http://dx.doi.org/10.1016/j.neucli.2006.04.005.

Carretié, L., Hinojosa, J.A., Martín-Loeches, M., Mercado, F., Tapia, M., 2004. Automatic attention to emotional stimuli: neural correlates. Human Brain Mapping 22 (4), 290–299, http://dx.doi.org/10.1002/hbm.20037.

Carretié, L., Martín-Loeches, M., Hinojosa, J.A., Mercado, F., 2001. Emotion and attention interaction studied through event-related potentials. Journal of Cognitive Neuroscience 13 (8), 1109–1128, http://dx.doi.org/10.1162/089892901753294400.

Dawson, G., Webb, S.J., McPartland, J., 2005. Understanding the nature of face processing impairment in autism: insights from behavioral and electrophysiological studies. Developmental Neuropsychology 27 (3), 403–424, http://dx.doi.org/10.1207/s15326942dn2703_6.

Dennis, T.A., Chen, C.C., 2007. Neurophysiological mechanisms in the emotional modulation of attention: the interplay between threat sensitivity and attentional control. Biological Psychology 76 (1/2), 1–10, http://dx.doi.org/10.1016/j.biopsycho.2007.05.001.

Eimer, M., 2000. The face-specific N170 component reflects late stages in the structural encoding of faces. Neuroreport 11 (10), 2319–2324.

Eimer, M., Gosling, A., Nicholas, S., Kiss, M., 2011. The N170 component and its links to configural face processing: a rapid neural adaptation study. Brain Research 1376, 76–87, http://dx.doi.org/10.1016/j.brainres.2010.12.046.

Eimer, M., Holmes, A., McGlone, F.P., 2003. The role of spatial attention in the processing of facial expression: an ERP study of rapid brain responses to six basic emotions. Cognitive, Affective and Behavioral Neuroscience 3 (2), 97–110.

Eysenck, M.W., 1997. Anxiety and Cognition: A Unified Theory. Psychology Press, Hove, UK.

Goldin, P.R., Manber, T., Hakimi, S., Canli, T., Gross, J.J., 2009. Neural bases of social anxiety disorder: emotional reactivity and cognitive regulation during social and physical threat. Archives of General Psychiatry 66 (2), 170–180, http://dx.doi.org/10.1001/archgenpsychiatry.2008.525.

Hillyard, S.A., Vogel, E.K., Luck, S.J., 1998. Sensory gain control (amplification) as a mechanism of selective attention: electrophysiological and neuroimaging evidence. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 353 (1373), 1257–1270, http://dx.doi.org/10.1098/rstb.1998.0281 (Research Support, Non-U.S. Gov't Research Support, U.S. Gov't, Non-P.H.S. Research Support, U.S. Gov't, P.H.S.).

Horley, K., Williams, L.M., Gonsalvez, C., Gordon, E., 2003. Social phobics do not see eye to eye: a visual scanpath study of emotional expression processing. Journal of Anxiety Disorders 17 (1), 33–44.

Horley, K., Williams, L.M., Gonsalvez, C., Gordon, E., 2004. Face to face: visual scanpath evidence for abnormal processing of facial expressions in social phobia. Psychiatry Research 127 (1/2), 43–53, http://dx.doi.org/10.1016/j.psychres.2004.02.016.

Itier, R.J., Alain, C., Sedore, K., McIntosh, A.R., 2007. Early face processing specificity: it's in the eyes! Journal of Cognitive Neuroscience 19 (11), 1815–1826.

Itier, R.J., Taylor, M.J., 2002. Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. NeuroImage 15, 353–372.

Itier, R.J., Taylor, M.J., 2004. Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. NeuroImage 21 (4), 1518–1532, http://dx.doi.org/10.1016/j.neuroimage.2003.12.016.

Klumpp, H., Amir, N., 2009. Examination of vigilance and disengagement of threat in social anxiety with a probe detection task. Anxiety, Stress, and Coping 22 (3), 283–296, http://dx.doi.org/10.1080/10615800802449602.

Kolassa, I.T., Kolassa, S., Bergmann, S., Lauche, R., Dilger, S., Miltner, W.H.R., Musial, F., 2009. Interpretive bias in social phobia: an ERP study with morphed emotional schematic faces. Cognition and Emotion 23 (1), 69–95, http://dx.doi.org/10.1080/02699930801940461 (article).

Kolassa, I.T., Kolassa, S., Musial, F., Miltner, W.H.R., 2007. Event-related potentials to schematic faces in social phobia. Cognition and Emotion 21 (8), 1721–1744.

Kolassa, I.T., Miltner, W.H.R., 2006. Psychophysiological correlates of face processing in social phobia. Brain Research 1118 (1), 130–141, http://dx.doi.org/10.1016/j.brainres.2006.08.019.

Kolassa, I.T., Musial, F., Kolassa, S., Miltner, W.H.R., 2006. Event-related potentials when identifying or color-naming threatening schematic stimuli in spider phobic and non-phobic individuals. BMC Psychiatry 6., http://dx.doi.org/10.1186/1471-244x-6-38.

Lee, S.H., Park, G.H. (2011). Psychophysiological Markers of Anxiety Disorders and Anxiety Symptoms, in: V. Kalinin (Ed.), Anxiety Disorders. Available from: http://www.intechopen.com/books/anxiety-disorders/psychophysiological-markers-of-anxiety-disorders-and-anxiety-symptoms

Liebowitz, M.R., 1987. Social phobia. In: Ban, T.A., Pichot, P., Poldinger, W. (Eds.), Modern Problems of Pharmacopsychiatry, 22. Karger, Basel, pp. 141–173.

Linkenkaer-Hansen, K., Palva, J.M., Sams, M., Hietanen, J.K., Aronen, H.J., Ilmoniemi, R.J., 1998. Face-selective processing in human extrastriate cortex around 120 ms after stimulus onset revealed by magneto- and electroencephalography. Neuroscience Letters 253 (3), 147–150.

Lundqvist, D., Flykt, A., Öhman, A., 1998. The Karolinska Directed Emotional Faces – KDEF. Karolinska Institutet, Stockholm.

MacLeod, C.M., 2001. Half a century of research on the Stroop effect: an integrative review. Psychological Bulletin 109 (2), 163–203.

Maidenberg, E., Chen, E., Craske, M., Bohn, P., Bystritsky, A., 1996. Specificity of attentional bias in panic disorder acid social phobia. Journal of Anxiety Disorders 10 (6), 529–541, http://dx.doi.org/10.1016/s0887-6185(96)00028-x.

Mattia, J.I., Heimberg, R.G., Hope, D.A., 1993. The revised Stroop color-naming task in social phobics. Behaviour Research and Therapy 31 (3), 305–313, http://dx.doi.org/10.1016/0005-7967(93)90029-t.

McTeague, L.M., Shumen, J.R., Wieser, M.J., Lang, P.J., Keil, A., 2011. Social vision: sustained perceptual enhancement of affective facial cues in social anxiety. NeuroImage 54 (2), 1615–1624, http://dx.doi.org/10.1016/j.neuroimage.2010.08.080.

Mogg, K., Bradley, B.P., 2002. Selective orienting of attention to masked threat faces in social anxiety. Behaviour Research and Therapy 40 (12), 1403–1414, PII: S0005-7967(02)00017-7.

Mogg, K., Philippot, P., Bradley, B.P., 2004. Selective attention to angry faces in clinical social phobia. Journal of Abnormal Psychology 113 (1), 160–165, http://dx.doi.org/10.1037/0021-843x.113.1.160.

Mühlberger, A., Wieser, M.J., Herrmann, M.J., Weyers, P., Tröger, C., Pauli, P., 2009. Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. Journal of Neural Transmission 116 (6), 735–746, http://dx.doi.org/10.1007/s00702-008-0108-6.

Pizzagalli, D., Regard, M., Lehmann, D., 1999. Rapid emotional face processing in the human right and left brain hemispheres: an ERP study. Neuroreport 10 (13), 2691–2698.

Rossignol, M., Campanella, S., Maurage, P., Heeren, A., Falbo, L., Philippot, P., 2012a. Enhanced perceptual responses during visual processing of facial stimuli in young socially anxious individuals. Neuroscience Letters 526 (1), 68–73, http://dx.doi.org/10.1016/j.neulet.2012.07.045.

Rossignol, M., Philippot, P., Bissot, C., Rigoulot, S., Campanella, S., 2012b. Electrophysiological correlates of enhanced perceptual processes and attentional capture by emotional faces in social anxiety. Brain Research 1460, 50–62.

Rossion, B., Delvenne, J.F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., Guerit, J.M., 1999. Spatio-temporal localization of the face inversion effect: an event-related potentials study. Biological Psychology 50 (3), 173–189.

Schmitz, J., Scheel, C.N., Rigon, A., Gross, J.J., Blechert, J., 2012. You don't like me, do you? Enhanced ERP responses to averted eye gaze in social anxiety. Biological Psychology 91 (2), 263–269, http://dx.doi.org/10.1016/j.biopsycho.2012.07.004.

Schupp, H.T., Junghöfer, M., Öhman, A., Weike, A.I., Stockburger, J., Hamm, A.O., 2004. The facilitated processing of threatening faces: an ERP analysis. Emotion 4 (2), 189–200, http://dx.doi.org/10.1037/1528-3542.4.2.189.

Schupp, H.T., Junghofer, M., Weike, A.I., Hamm, A.O., 2003. Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. Neuroreport 14 (8), 1107–1110.

Spielberger, C.D., Gorsuch, R.L., Lusthene, R., Vagg, P.R., Jacobs, G.A., 1983. Manual for the State-Trait Anviety Inventory. Consulting Psychology Press, Palo Alto, CA.

Staugaard, S.R., 2010. Threatening faces and social anxiety: a literature review. Clinical Psychology Review 30 (6), 669–690, http://dx.doi.org/10.1016/j.cpr.2010.05.001.

Stroop, J.R., 1935. Studies of interference in serial verbal reactions. Journal of Experimental Psychology 18 (6), 643–662, http://dx.doi.org/10.1037/h0054651.

Taylor, M.J., 2002. Non-spatial attentional effects on P1. Clinical Neurophysiology 113 (12), 1903–1908, http://dx.doi.org/10.1016/s1388-2457(02)00309-7.

Taylor, M.J., Khan, S.C., 2000. Top-down modulation of early selective attention processes in children. International Journal of Psychophysiology 37 (2), 135–147, http://dx.doi.org/10.1016/s0167-8760(00)00084-2.

van Peer, J.M., Spinhoven, P., Roelofs, K., 2010. Psychophysiological evidence for cortisol-induced reduction in early bias for implicit social threat in social phobia. Psychoneuroendocrinology 35 (1), 21–32, http://dx.doi.org/10.1016/j.psyneuen.2009.09.012.

Vuilleumier, P., Pourtois, G., 2007. Distributed and interactive brain mechanisms during emotion face perception: evidence from functional neuroimaging. Neuropsychologia 45 (1), 174–194, http://dx.doi.org/10.1016/j.neuropsychologia.2006.06.003 (Research Support, Non-U.S. Gov't Review).

Wieser, M.J., Pauli, P., Weyers, P., Alpers, G.W., Muhlberger, A., 2009. Fear of negative evaluation and the hypervigilance-avoidance hypothesis: an eye-tracking study. Journal of Neural Transmission 116 (6), 717–723, http://dx.doi.org/10.1007/s00702-008-0101-0.

Wieser, M.J., Pauli, P., Reicherts, P., Muhlberger, A., 2010. Don't look at me in anger! Enhanced processing of angry faces in anticipation of public speaking. Psychophysiology 47 (2), 271–280, http://dx.doi.org/10.1111/j.1469-8986.2009.00938.x.

Williams, J.M.G., Mathews, A., MacLeod, C., 1996. The emotional Stroop task and psychopathology. Psychological Bulletin 122 (1), 3–24.

Yao, S.N., Note, I., Fanget, F., Albuisson, E., Bouvard, M., Jalenques, I., Cottraux, J., 1999. Social anxiety in social phobics: validation of Liebowitz's social anxiety scale – French version. Encephale-Revue De Psychiatrie Clinique Biologique Et Therapeutique 25 (5), 429–435.