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Am I really seeing what's around me? An ERP study on social anxiety under speech induction, uncertainty and social feedback

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ABSTRACT

Cognitive models of social anxiety propose that socially anxious individuals engage in excessive self-focusing attention when entering a social situation. In the present study, speech anxiety was induced to socially anxious and control participants. Event-related potentials were recorded while participants performed a perceptual judgement task using distinct or ambiguous stimuli, before and after social feedback. Disputed feedback led to more revisions and decreased levels of confidence, especially among socially anxious individuals. Prior feedback, greater occipital P1 amplitudes in both groups for ambiguous probes indicated heightened sensory facilitation to ambiguous information, and greater anterior N1 amplitudes for ambiguous stimuli in highly anxious participants suggested anticipation of negative feedback in this group. Post-feedback, P1, N1 and LPP amplitudes were reduced overall among socially anxious individuals indicating a reduction in sensory facilitation of visual information. These results suggest excessive self-focusing among socially anxious individuals, possibly linked to anticipation of an anxiety-provoking social situation.

1. Introduction

Social anxiety disorder (SAD) is one of the most common psychiatric disorders with a prevalence rate of 12–15% among the general population, and only 10–20% of individuals with SAD seeking therapeutic counselling (Furmark et al., 1999). A wealth of behavioural research has assessed attentional biases in socially anxious individuals by measuring reaction times and eye movements in various paradigms using emotional face expressions (e.g. Mattia, Heimberg, & Hope, 1993; Pishyar, Harris, & Menzies, 2004; Buckner, Maner, & Schmidt, 2010; for a review see Cisler & Koster, 2010). Nevertheless, the mixed results reported in the literature show that it remains unclear whether attentional biases involve excessive attention to threat (Gamble & Rapee, 2010; Boll, Bartholomaeus, Peter, Lupke, & Gamer, 2016; Holas, Krejtz, Cypryanska, & Nezlek, 2014), difficulty to disengage attention from threat (Amir, Elias, Klumpp, & Przeworski, 2003; Moriya & Tanno, 2011), attentional avoidance from threat (e.g. Moukheiber et al., 2010), impaired inhibition control and shifting functions (Eysenck & Derakshan, 2011; Taylor, Cross, & Amir, 2016) or even the absence of the positive attentional bias present in non-anxious populations (Schofield, Inhoff, & Coles, 2013). SAD has also been associated with both hypervigilance and attentional avoidance (Chen, Thomas, Clarke, Hickie, & Guastella, 2015). Several recent studies have explored these attentional components using eye-tracking measures. For example, Moukheiber et al. (2010) observed a lower number of fixations and dwell time in the eye area for the different basic emotions, making eye avoidance a behavioural phenotype in SAD. Other studies (Gamble & Rapee, 2010; Holas et al., 2014; Boll et al., 2016) observed hypervigilance in early stages at around 150 ms, manifested by a *greater* proportion of fixations towards emotional faces or faster initial orienting towards negative face emotions.

According to the most prominent cognitive models of social anxiety, the disorder is characterised by heightened self-focused attention when anticipating or engaging in a social situation (Clark & Wells, 1995), and by an impaired attentional disengagement from threatening social stimuli (Mathews & Mackintosh, 1998). This self-focused attention is characterised by negative self-perception and heightened ruminations when evaluating one's performance (Zou & Abbott, 2012). Similarly, in

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social situations, fear of rejection leads socially anxious individuals to anticipate negative evaluations by others and overestimate the costs of a positive feedback. This is reflected by deactivation of medial prefrontal brain areas relative to the anticipation of negative feedback (reflecting decreased self-focus) and medial prefrontal and insular hyperactivation, regardless of feedback valence, in the feedback processing stage (reflecting increased self-focus) (Heitmann et al., 2014). Consequently, one of the features of social anxiety is the extent to which interaction and feedback by the social environment affects the anxious individual's metacognition and certainty in their judgements and perceptions (Rachman, Grüter-Andrew, & Shafran, 2000). Indeed, in situations of uncertainty, socially anxious individuals show a negative interpretation bias and tend to interpret ambiguous information as more threatening than non-socially anxious individuals (Constans, Penn, Ihen, & Hope, 1999; Counsell et al., 2017), placing intolerance of uncertainty as an important transdiagnostic variable in SAD (Boelen & Reijntjes, 2009; Carleton, Collimore, & Asmundson, 2010).

In previous articles, we (Zanesco, Tipura, Posada, Clément, & Pegna, 2018; Zanesco, Tipura, Clément, & Pegna, 2019) devised an ERP paradigm that enabled the early perceptual brain responses to ambiguous stimuli to be measured under various social constraints. In this procedure, distinct or ambiguous colour stimuli were presented to participants, who were asked to determine the colour and rate the degree of certainty of their judgement. They were then given alleged social feedback that either endorsed or disputed their response. The same stimulus was then shown again, and participants were given the option to maintain or revise their decision and re-rate their confidence. ERPs were measured in response to both the initial and subsequent presentation of the colour stimulus to establish the pattern of changes associated with social dispute. From a behavioural perspective, conflicting social feedback led to an increase in the number of revised judgements by the participants, a phenomenon that has long been described by social psychology (Asch, 1951). The ERP results further showed that stimulus ambiguity and social feedback both affected the electrical brain response as early as 100 ms after stimulus presentation, pointing to an early modulation of the perceptual and attentional brain response following social information. In view of the increased susceptibility of socially anxious individuals to ambiguity and social feedback, we asked whether similar patterns of activation would be observed in anxious individuals, albeit to a greater extent due to their increased attentional activation, or whether the effects of social anxiety would involve later, controlled processes of self-reflection associated with metacognitive awareness (Desender, Van Opstal, Hughes, & Van den Bussche, 2016).

The present study focused on the modulation of cognitive ERPs processes following opposition or approval by peers during judgements of perceptually ambiguous visual stimuli. Participants presenting different levels of social anxiety were investigated and anxiety was further enhanced by leading all participants to believe they would be presenting their observations and impressions regarding the experiment to three psychologists immediately afterwards.

Since ambiguity and social disagreement increase feelings of uncertainty in the general population (Cialdini & Goldstein, 2004), we hypothesised that higher levels of social anxiety would lead to even more response revisions during the task following disagreement at the behavioural level. Additionally, we expected socially anxious subjects to present lower levels of confidence for ambiguous compared to distinct stimuli, but higher levels of confidence following an endorsing social cue compared to a disputed cue. For the electrophysiological data, we focused on the early visual P1 and N1 components locked to the presentation of the probe stimuli, before and after social feedback, as well as the late positive potential (LPP). It was expected that initial presentation of ambiguous stimuli would produce greater P1/N1/LPP amplitudes than initial distinct ones due to increased attentional engagement in anxious and non-anxious groups (Zanesco et al., 2018; Zanesco et al., 2019; Luck, Heinze, Mangun, & Hillyard, 1990), in line with our previous observations. We also predicted that after social feedback, socially disputed ambiguous stimuli would generate greater P1/N1/LPP amplitudes than socially endorsed ones. In a previous study, the P1 amplitude was larger for ambiguous stimuli following disputed social feedback, as compared to the initial presentation of the same stimuli (Zanesco et al., 2018), suggesting that social feedback influences early perceptual brain processes. These effects were expected to be larger for the socially anxious group compared to controls. Finally, the electrical response to the actual social feedback cue (a face displaying joy or disgust) was also examined and compared across conditions and participant groups.

2. Materials and methods

2.1. Participants

Forty-seven paid students were recruited for this study using posters placed at the University of Geneva. Four participants were excluded due to high number of artefacts. The final sample was therefore composed of 43 participants (30 females and 13 males; mean age = 23.0 ± 2.7). All were right-handed and had normal or corrected to-normal vision. Twenty-two subjects had no self-reported psychiatric or neurological disorder, while 21 participants reported having social anxiety and were recruited on this basis. Participants were allocated to either the social anxious group (21 subjects; 18 women) or the control group (22 subjects; 13 women) upon completion of the French version (Yao et al., 1999) of the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987). The LSAS is a 24-item scale scored on a 0–3 Likert scale assessing two key dimensions of social anxiety across a variety of situations. The first dimension refers to the level of fear or anxiousness in a particular situation. The second dimension refers to how often the situation is avoided. Scores range from 0 to 144 points, and the cut off is situated at 56 points representing moderate anxiety. Scores above 80 are associated with severe social anxiety and scores above 95 points, with very severe social anxiety. Thus, subjects scoring at or above 56 constituted the social anxious group and subjects scoring below the cut-off made up the control group. The French version of the LSAS has been shown to present a high empirical and concurrent validity (*r*-Pearson between 0.49 and 0.69) and it differentiates socially anxious subjects from non-clinical ones (Yao et al., 1999). None of the participants were formally diagnosed with social anxiety and none were students in psychology. The mean LSAS score for the social anxious group was 79.23 ± 17.31 and 33.22 ± 12.41 for the control group.

They were paid 50 Swiss francs for their participation. The study was approved by the local ethics committee (University of Geneva) and was performed in agreement with the Declaration of Helsinki.

2.2. Stimuli and experimental procedure

The procedure and stimuli have been described elsewhere (Zanesco et al., 2018). A fixation cross was presented (400–600 ms) followed by the probe stimulus (700 ms) that was a square stimulus (5.73°) that was either of a distinct blue or green colour (16 stimuli), or of an ambiguous green/blue hue (16 stimuli controlled for isoluminance, ranging from 28.17 cd/m2 to 30.72 cd/m2). After the stimulus, a response prompt (self-paced) appeared asking the participant to decide whether the stimulus was green or blue. Participants were then asked to rate their level of certainty in their response on a scale from 1 to 5. They were then presented with a face (1000 ms) which they were told reflected the judgement of the majority of previous participants, and which expressed either disgust (disagreement) or joy (endorsement). In order to maintain credibility, our design did not include any social disagreement for distinct probes and each participant had the same number of trials for the different conditions. Then, a fixation cross was presented (400–600 ms) and the exact same sequence was repeated in the same order with the probe stimulus (700 ms – identical to the first presentation in the trial) followed by a response prompt (self-paced) asking the participant to decide whether the stimulus was green or blue. Participants were then asked to rate their level of certainty in their response on a scale from 1 to 5. The faces used for social feedback were 10 male and 10 female identities expressing happiness or disgust, taken from the Radboud Faces Database (Langner et al., 2010) (see Fig. 1). The experiment was divided in three blocs of 120 trials.

Prior to the recording, participants were asked to complete the French version of the Liebowitz Social Anxiety Scale (LSAS) (Liebowitz, 1987). Then, social anxiety was induced by telling participants that at the end of the task, three psychologists would ask them to give their subjective feeling during the experiment.

2.3. EEG acquisition

EEG was recorded using a 64-channel Biosemi Active-Two system (Amsterdam, Netherlands) with AG/AgC1 electrodes positioned according to the extended 10–20 system. Four additional flat electrodes were placed on the outer canthi of the eyes and above and under the right eye, in order to capture the eye movements and blinks. Each active electrode is represented with an impedance value, which was kept below 20 kΩ for each participant. The EEG was continuously recorded with a sampling rate of 1024 Hz. Data was re-referenced off-line against the average reference.

2.4. EEG processing

Standard processing of EEG data was done offline using the software Brain Vision Analyzer V.2 (Brain Products, Gilching, Germany). The data were downsampled to 512 Hz and filtered between 0.1 Hz and 30 Hz (order: 2). Bad electrodes were interpolated using a spherical spline (1.5% of the electrodes were interpolated). Eye movements and blinks were corrected (Gratton, Coles, & Donchin,1983) and trials containing artefacts (automatic inspection; minimal allowed amplitude: −100 μV; maximal allowed amplitude: 100 μV) were removed (13%).

2.5. Behavioural analysis

Behaviourally, mean confidence ratings were compared for each participant separately for initial and post-feedback presentations and for each condition. Additionally, fluctuations in confidence ratings between initial and post-feedback probes were also examined. Finally, trials in which participants revised their judgement after social feedback were counted as “revisions”. Mean number of revisions was calculated according to the ambiguity of the probe and the valence of the social cue.

Statistical analysis of mean confidence rates was performed using two repeated measures ANOVAs. For the initial presentation of stimuli, a 2 × 2 ANOVA was carried out using the mean confidence rate as the dependent variable, the group (control / social anxious) as the between-subject factor and the condition (initial ambiguous / initial distinct) as the within subject factor. To examine the effect of social feedback on subjective confidence, a 2 × 3 ANOVA was carried out using mean confidence rate of the second presentation as the dependent variable, the group (control /social anxious) as the between-subject factor and the condition (ambiguous endorsed/ distinct endorsed/ ambiguous disputed) as the within-subject factor. To examine the increase or decrease in confidence rate between initial and post-feedback probes, we used a 2 × 3 repeated measures ANOVA, with the percentage of fluctuation as the dependent variable, the group (control / social anxious) as the between-subject factor and the condition (ambiguous endorsed/ distinct endorsed/ ambiguous disputed) as the within-subject factor.

The number of revisions for each group was investigated using an ANOVA with the mean number of revisions as the dependent variable, the group (control /social anxious) as the between-subject factor and the condition (ambiguous endorsed/ distinct endorsed/ ambiguous disputed) as the within-subject factor.

Since the ratio of men vs. women was not equal in our sample and social evaluations are sensitive to gender effects (Wiggert, Wilhelm, Derntl, & Blechert, 2015), we performed the same analysis by adding the

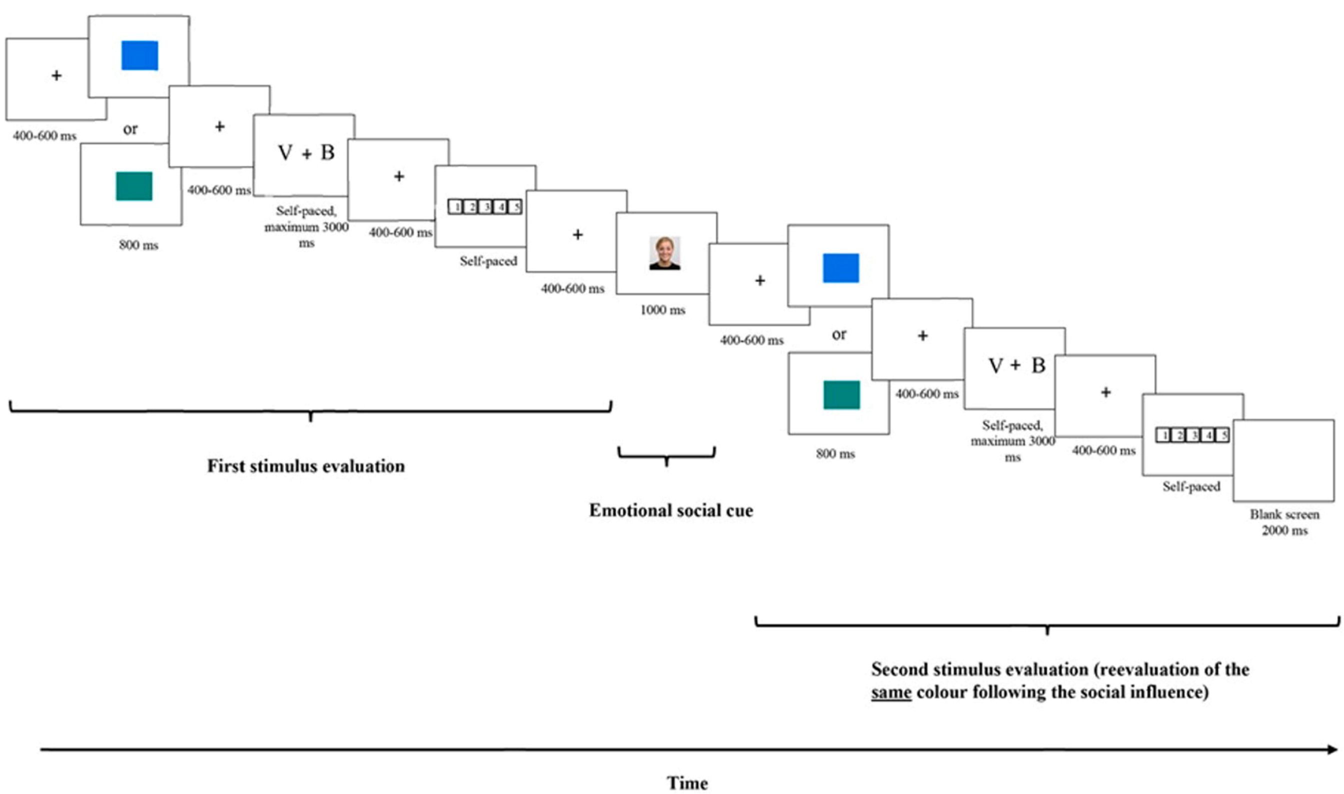

Fig. 1. Experimental procedure. The trial started with either a blue or a green square, followed by the social feedback and a second evaluation of the same coloured square.

gender of face stimuli as a within subjects factor and the participant's gender as a between subjects factor, and did not find any evidence for the influence of gender on participants responses (all ps>.05). Furthermore, we performed all the analyses with only female participants, and the effects did not differ from the initial results.

2.6. Electrophysiological recordings and analyses

ERPs were computed for distinct and ambiguous stimuli in the initial presentation from − 200 to 700 ms using the 200 ms pre-stimulus period for baseline correction. For the post-feedback stimulus presentations, ERPs were computed for ambiguous endorsed, ambiguous disputed and distinct endorsed conditions. For the social feedback presentation, ERPs were computed for faces expressing agreement (happy expressions) and disagreement (disgust expressions). The latter, following ambiguous stimuli and the former following ambiguous or distinct stimuli. Following visual inspection, the P1, N1 and LPP amplitudes were retained for statistical investigation for the initial and post-feedback presentations. For the social feedback presentation, we focused on the P1 and the N170 components. When necessary, adjusted p-values and degrees of freedom were used to control for sphericity (Greenhouse-Geisser correction).

2.6.1. Initial stimulus presentations

Visual inspection showed differences on the posterior P1, anterior N1 and LPP components. The time windows for analysis were subsequently determined based on the peaks and means observed in the grand averages across all conditions using a collapsed localiser. Peak amplitudes were used for the P1 and N1 components, and additional mean amplitudes were performed to confirm the results. The P1 peaks (80–140 ms) were determined using a semi-automatic peak detection method and were measured over electrodes on the left (O1), right (O2) and midline (Oz). To be sure that the results do not depend on the size of the window, two time windows were used for the mean amplitude of the P1 component: 90–130 ms and 100–120 ms. Peaks for the anterior N1 (60–150 ms) were measured over the left (FC1), midline (FCz) and right (FC2) frontal electrodes. Two time windows were used for the mean amplitude of the N1 component: 80–140 ms and 90–130 ms. The LPP mean amplitude was computed for anterior and posterior scalp sites between 300 ms and 500 ms. For the posterior LPP, electrodes CP1, CPz and CP2 were used; for the anterior LPP, electrodes F1, Fz and F2 were used.

Repeated measures ANOVAs were carried out for each component using the group (control/ social anxious) as between-subject factor, difficulty (initial distinct / initial ambiguous) and laterality (left / midline / right) as within subject factors.

2.6.2. Post-feedback stimulus presentations

The same electrodes and time windows were used to compute the peak and mean amplitudes on the P1, N1 and LPP components for the post-feedback stimulus presentations.

Repeated measures ANOVAs were carried out for each component using the group (control/ social anxious) as between-subject factor and the three conditions (distinct endorsed / ambiguous endorsed/ ambiguous disputed) and laterality (left / midline / right) as within subject-factors.

2.6.3. Social feedback presentations

The P1 and N170 time-locked to the social feedback were identified based on the grand average across all conditions. In this manner, the time window for the P1 peak amplitude was observed between 60 ms and 130 ms and measured over posterior left (PO7, O1) and right (PO8, O2) electrodes. Two time windows were used for the mean amplitude of the P1 component: 70–120 ms and 80–110 ms. The N170 peak amplitudes were measured on temporo-parietal sites (left: P7, P9, PO7 and right: P8, P10, PO8) between 110 ms and 200 ms. Two time windows were used for the mean amplitudes of the N170 component: 130–180 ms and 140–170 ms.

Repeated measures ANOVAs were carried out for each component using the group (control/ social anxious) as between-subject factor, conditions (distinct endorsed / ambiguous endorsed/ ambiguous disputed) and laterality (left / right) as within subject-factors.

3. Results

3.1. Behavioural results

Results of the self-report questionnaire revealed that 23% (10 subjects) of participants always believed in the social feedback, 63% (27 subjects) stated that they believed in it occasionally, while 14% reported not believing in the social feedback (6 subjects). The latter group nevertheless revised their judgements on 6.9% of the trials on average, following social feedback, compared to 7.2% for those stating occasional or systematic belief in the feedback. A t-test was performed on the credibility scores of each group to test if participants differed as a function of credibility in the social cue and did not reveal any significant difference between the socially anxious group and the control group ($t(41) = 0.47$, $p > .05$).

The ANOVA performed on the mean number of revisions revealed a significant main effect of group ($F(1, 41) = 12.1$, $p < .05$), of condition ($F(1.2, 48.2) = 55.7$, $p < 10^{-8}$), as well as an interaction between group and condition ($F(1.2, 48.2) = 7.7$, $p < .05$). The number of revisions was significantly higher in the social anxious group relative to the control group. For the main effect of condition, post-hoc comparisons revealed that the mean number of revisions was significantly higher following disputed feedback compared to both endorsed conditions ($p < 10^{-4}$). For the interaction between group and condition, post-hoc comparisons using Tukey tests revealed that the mean number of revisions was significantly higher for disputed ambiguous probes in the social anxious group compared to the control group ($p < 10^{-3}$).

The ANOVA performed on the mean confidence ratings for the initial probes revealed a main effect of condition ($F(1, 41) = 185.2$, $p < 10^{-15}$). Mean confidence ratings were significantly higher for initial distinct probes compared to initial ambiguous probes, and this for both groups. The effect of group ($F(1,41) = 0.7$, $p > .05$) and the interaction between group and condition ($F(1,41) = 2.3$, $p > .05$) were not significant. After the social feedback, the ANOVA showed a main effect of condition ($F(1.7, 72.9) = 122.5$, $p < 10^{-10}$). Post-hoc comparisons using Tukey tests revealed that the significant differences were between all three conditions (distinct endorsed: 96.8%, ambiguous endorsed: 77.7%, ambiguous disputed: 71.8%), with the lowest mean confidence rate for ambiguous disputed. Post-feedback, the effect of group ($F(1,41) = 0.5$, $p > .05$) and the interaction between group and condition ($F(1.7, 72.9) = 2.3$, $p > .05$) were not significant.

Finally, an ANOVA for repeated measures was carried out on the percentage fluctuation between initial and post-feedback confidence ratings. This analysis revealed a main effect of condition ($F(1.3, 56.7) = 17$, $p < 10^{-4}$). Post-hoc comparisons using Tukey tests revealed a significant increase in confidence rate from initial to post-feedback probes after ambiguous endorsed probes compared to distinct endorsed probes ($p < .05$) and to ambiguous disputed probes ($p < .05$). The interaction between group and condition was also significant ($F(1.3, 56.7)= 6.3$, $p < .05$). Post-hoc comparisons showed significant differences between the three conditions in the anxious group with ambiguous and distinct endorsed conditions leading to an increase in confidence ratings and the ambiguous disputed condition leading to a decrease in confidence rating ($p < .05$). These differences were not observed in the control group. Moreover, the decrease in confidence ratings in the ambiguous disputed conditions was significantly higher in the anxious compared to the control group ($p < .05$). The effect of group was not significant ($F(1, 41)= 0.6$, $p > .05$).

In summary, the behavioural results showed that most participants considered the social feedback to be credible and adjusted their subjective confidence ratings accordingly. The level of confidence was higher for distinct probes compared to ambiguous ones and higher for ambiguous endorsed probes compared to ambiguous disputed probes. Although this pattern was similar for both groups, socially anxious individuals showed a tendency to increase their confidence rates after endorsed social cues and to decrease their confidence ratings after disputed social feedback in comparison to controls. A summary of means and standard deviations for each condition and each group is presented in Table 1.

3.2. Electrophysiological results

3.2.1. Initial stimulus presentation

3.2.1.1. Posterior P1 amplitude. The repeated measures ANOVA showed a significant main effect of condition ($F(1, 41) = 48.5, p < 10^{-6}$), and an interaction between condition and laterality ($F(1.9, 79.6) = 7.1, p < .05$). For the main effect of condition, the P1 was significantly larger for the initial ambiguous probes, compared to the presentation of initial distinct probes. These results were confirmed with mean amplitude analyses, where the significance or non-significance of effects were the same as peak amplitude analyses.

3.2.1.2. Anterior N1 amplitude. The ANOVA performed on N1 peak amplitudes revealed a main effect laterality ($F(1.9, 79.9) = 7.2, p < .05$); the N1 was found to be significantly larger over midline hemisphere leads compared to both left and right hemisphere leads ($p < .05$). The main effect of condition was also significant ($F(1,41) = 5.8, p < .05$) with ambiguous stimuli leading to more important amplitude than distinct ones. Finally, the interaction between condition and group was also significant ($F(1,41) = 5, p < .05$). Post-hoc comparisons showed one significant difference: in the anxious group only, ambiguous stimuli lead to more negative amplitude than distinct stimuli ($p < .05$) across all electrodes (Fig. 2). These results were confirmed with mean amplitude analyses.

3.2.1.3. LPP. For the posterior region of interest (CP1, CPz, CP2), the effect of condition was significant ($F(1,41) = 44.68, p < 10^{-6}$), with distinct trials leading to higher mean amplitude than ambiguous trials (Fig. 3). None of the effects reached significance on anterior electrodes (all ps>.05).

Table 1
Means and standard deviations (SD) in each condition and each group. S1: Initial stimulus presentation; S2: Post-feedback stimulus presentation.

	Socially anxious group					
	Mean confidence ratings		Fluctuations		Number of revisions	
	Mean	SD	Mean	SD	Mean	SD
S1 Ambiguous	73.03	11.33				
S1 Distinct	93.38	11.12				
S2 Ambiguous endorsed	78.86	12.21	8.43%	10.75%	7.24	5.74
S2 Ambiguous disputed	69.40	13.28	-5.15%	8.74%	25.05	17.01
S2 Distinct	95.11	9.92	2.10%	3.66%	1.14	1.15
	Control group					
	Mean confidence ratings		Fluctuations		Number of revisions	
	Mean	SD	Mean	SD	Mean	SD
S1 Ambiguous	72.76	12.56				
S1 Distinct	98.22	3.26				
S2 Ambiguous endorsed	76.78	12.75	5.80%	8.03%	5.41	5.24
S2 Ambiguous disputed	74.11	12.45	1.99%	4.08%	12.59	4.99
S2 Distinct	98.48	2.80	0.30%	0.90%	1.23	1.69

3.2.2. Post-feedback stimulus presentation

3.2.2.1. Posterior P1 amplitude. The ANOVA performed on P1 peak amplitudes post-feedback probes revealed significant main effects of group ($F(1, 41) = 4.6, p < .05$), and condition ($F(1.6, 66.3) = 44.7, p < 10^{-9}$). P1 amplitudes were significantly larger for the control group than for the social anxious group. For the main effect of condition, post-hoc comparisons using Tukey tests revealed a larger P1 for the ambiguous conditions compared to the distinct endorsed condition ($p < 10^{-3}$). The interaction between condition and laterality was also significant ($F(3.6, 149.7) = 6.4, p < .05$). With mean amplitude analyses, the effect of group was not significant ($F(1, 41) = 2.7, p = .10$ for the 90–130 ms time window; $F(1, 41) = 3.0, p = .08$ for the 100–120 ms time window), all the other effects were confirmed.

3.2.2.2. Anterior N1 amplitude. The same repeated measures ANOVA for post-feedback probes showed main effects of group ($F(1, 41) = 7.5, p < .05$), condition ($F(1.9, 81.3) = 5.7, p < .05$), and laterality ($F(1.7, 70) = 13.3, p < 10^{-3}$). For the main effect of group, the anterior N1was significantly more negative for the control group than for the social anxious group (Fig. 4). For the main effect of condition, post-hoc comparisons using Tukey tests revealed that the early anterior negativity peak amplitude was significantly larger for ambiguous disputed than distinct endorsed stimuli. Additionally, the mean peak N1 amplitudes were significantly larger over midline hemisphere leads compared to left and right ones ($p < .05$). With mean amplitude analyses, these results were confirmed for the 90–130 ms time window. For the 80–140 ms time window, the effect of laterality was not significant ($F(1.8, 76.4) = 2.0, p = .14$), all the other effects were confirmed.

3.2.2.3. LPP. For the posterior region of interest (CP1, CPz, CP2), the effect of condition was significant ($F(2,82) = 5.95, p < .05$). Post-hoc Tukey tests showed that the difference between ambiguous disputed and distinct endorsed conditions was significant ($p < .05$). The interaction between group and condition ($F(2,82) = 4.56, p < .05$) was also significant. Post-hoc Tukey tests showed that both ambiguous conditions were significantly different from the distinct endorsed condition in the control group only (Fig. 5). On anterior electrodes (F1, Fz, F2), only the effect of group was significant ($F(1,41) = 11.46, p < .05$) with the control group showing a larger mean amplitude than the social anxious group.

3.2.3. Social feedback

3.2.3.1. Posterior P1 amplitude. None of the effects reached significance for the P1 amplitude following social feedback (all ps>.05).

3.2.3.2. N170 amplitude. The ANOVA performed on the N170 peak amplitude revealed main effects of condition ($F(1.7, 73.4) = 20.1, p < 10^{-6}$), laterality ($F(1, 41) = 21.2, p < 10^{-3}$), and an interaction between condition, laterality and group ($F(1.4, 59.9) = 4.7, p < .05$). Post-hoc comparisons showed that N170 amplitudes were significantly larger for the ambiguous endorsed condition compared to the distinct condition ($p < 10^{-2}$) and for the ambiguous disputed condition compared to the distinct condition ($p < 10^{-2}$). The N170 amplitude was significantly larger over the right hemisphere than over the left one. As for the triple condition x laterality x group interaction, post hoc Tukey tests showed that ambiguous endorsed and ambiguous disputed faces both lead to more negative amplitude than distinct faces in both hemispheres in the control group, while these differences are only present in the left

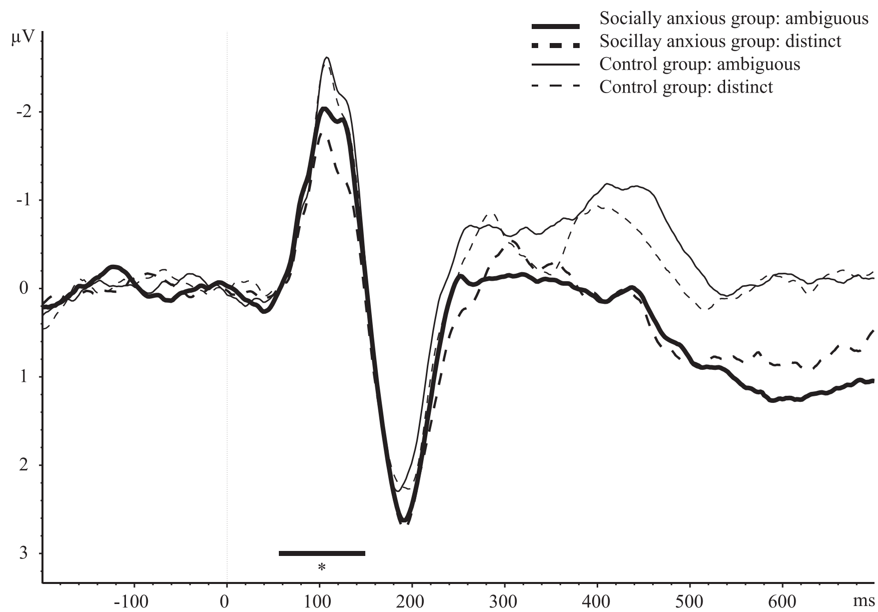

Fig. 2. ERPs for ambiguous and distinct probes presented before social feedback. Pooled ERP traces are shown across electrodes used for the computation of the anterior N1 for the two conditions of ambiguity and for the two groups (control vs social anxious). Thick lines: socially anxious group; thin lines: control group. Solid lines: ambiguous stimuli; dashed lines: distinct stimuli.

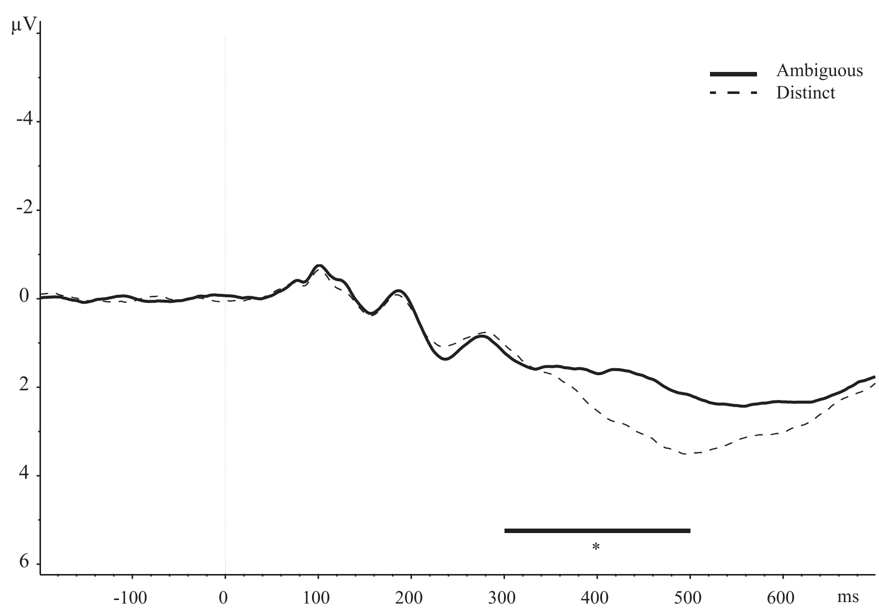

Fig. 3. ERPs for ambiguous and distinct probes presented before social feedback. Pooled ERP traces are shown across electrodes used for the computation of the posterior LPP for the two conditions of ambiguity. Solid line: ambiguous stimuli; dashed line: distinct stimuli.

hemisphere in the anxious group. With mean amplitude analyses, the triple interaction between condition, laterality and group was not significant ($F(1.4, 60.4)= 0.9$, $p = .36$ for the 130–180 ms time window; $F(1.5, 61.8)= 2.9$, $p = .07$ for the 140–170 ms time window), all the other effects were confirmed.

4. Discussion

The purpose of the present study was to explore the effect of perceptual uncertainty and social influence on early processes in a socially anxious population compared to healthy controls. In particular, the focus was on the neural responses to ambiguous stimuli that differed as to whether they were endorsed or contested by the alleged social group.

As expected, behavioural results showed that all participants, when faced with ambiguous stimuli, revised their judgements more often following social disagreement than following social endorsement. Importantly, the number of revisions after disputing feedback was higher in the social anxious group, confirming the stronger influence of disputing social feedback on social anxious individuals. Additionally, all participants presented lower confidence ratings for initial ambiguous probes compared to initial distinct probes. After social feedback, mean confidence ratings were lower for ambiguous disputed probes. However, socially anxious individuals showed a tendency to increase their confidence ratings compared to controls when social feedback endorsed their response, and to further decrease their subjective confidence level after disputed social feedback in comparison to controls, suggesting that social anxious subjects were more sensitive to social approval than healthy

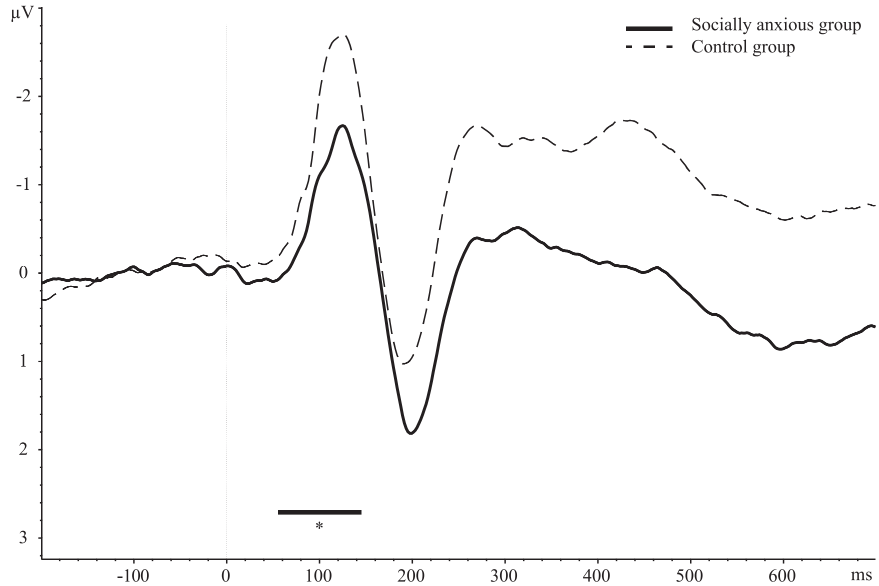

Fig. 4. ERPs for each group after social feedback. Pooled ERP traces are shown across electrodes used for the computation of the anterior N1 for the two groups. Solid line: socially anxious group; dashed line: control group.

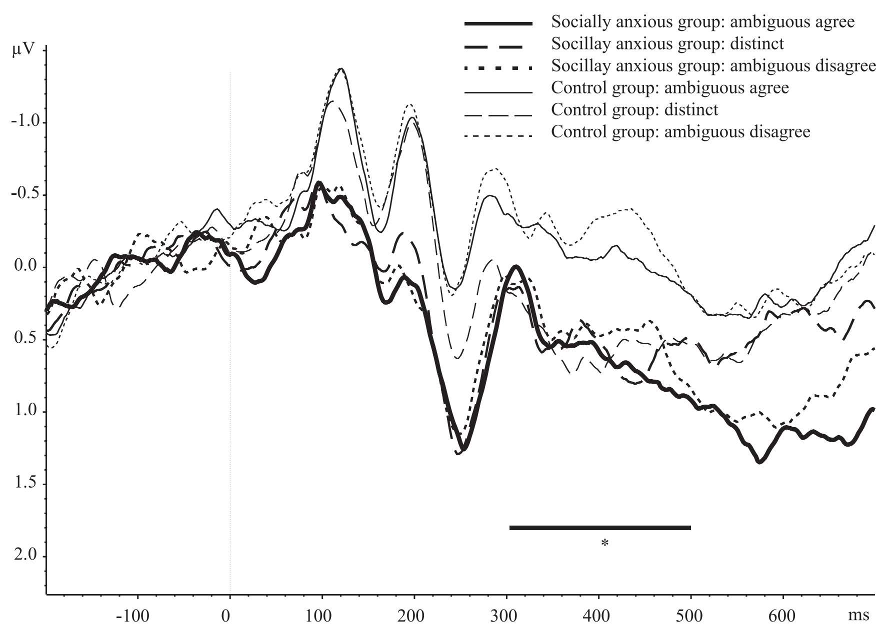

Fig. 5. ERPs for each group and each condition after social feedback. Pooled ERP traces are shown across electrodes used for the computation of the posterior LPP for the two groups and the three conditions. Thick lines: socially anxious group; thin lines: control group. Solid lines: ambiguous agree condition; dashed lines: distinct condition; dotted lines: ambiguous disagree condition.

subjects. The behavioural results indicate increased uncertainty in socially anxious subjects (e.g. Harrewijn, van der Molen, van Vliet, Tissier, & Westenberg, 2018) and are in line with cognitive-behavioural studies (e.g. Cisler & Koster, 2010) showing that socially anxious individuals fear social rejection and are less tolerant to uncertainty than healthy subjects (Rapee & Heimberg, 1997; Rossignol, Campanella, Bissot, & Philippot, 2013; Nelson, Hodges, Hajcak, & Shankman, 2015).

At the electrophysiological level, ERPs measured in response to ambiguous probes revealed enhanced P1 for both groups, starting at around 80 ms. The P1 was larger for initial ambiguous compared to distinct probes. This increase in P1 for ambiguous stimuli is in line with findings demonstrating the influence of uncertainty produced by perceptual instability of the visual probes (e.g. Dyson, 2011; Klink, van Wezel, & van Ee, 2012; Reuman, Jacoby, Fabricant, Herring, & Abramowitz, 2015) and corroborates the behavioural data indicating lower confidence rates for ambiguous probes compared to distinct ones. The more ambiguous the visual information, the stronger the brain will respond to it (Zeki, 2006). The anterior N1 response before social feedback distinguishes socially anxious participants from control ones and seems to reflect expectancy of negative feedback: the N1 was larger for ambiguous than distinct probes in the social anxious group only. The N1/N170 has recently been found to be strongly associated with expectancy violations in the perceptual domain, and as such are increasingly being recognised as prediction error signals (Allen-Davidian et al., 2021; Baker, Pegna, Yamamoto, & Johnston, 2020; Feuerriegel, Yook, Quek, Hogendoorn, & Bode, 2021; Johnston, Overell, Kaufman, Robinson, & Young, 2016; Johnston et al., 2017; Marzecová et al., 2018; Robinson, Breakspear, Young, & Johnston, 2020). As such, it is likely that the enhanced N1 resulted from stronger expectations of negative feedback in anxious participants. One recent study (Harrewijn et al., 2018), using a social judgement paradigm, observed an increased frontal N1 after expected rejection feedback and interpreted this result as a general pessimism bias as well as a hypervigilance to threatening stimuli in socially anxious individuals and a possible candidate endophenotype of SAD. If social anxiety is characterised by increased self-focus in social or performance situations, according to cognitive models of social anxiety, this cognitive process appears not only during or following these situations, but before the situation is encountered (Wells & Clark, 1997). While a distinct stimulus leads to expected acceptance, both acceptance and rejection are possible outcomes in the case of ambiguous stimuli. Our results therefore suggest a hypervigilance to these ambiguous stimuli and expected rejection in socially anxious participants, as reflected by the increase in N1 component following the initial ambiguous probes.

Interestingly, post-feedback P1 amplitudes were enhanced for controls compared to socially anxious individuals, suggesting ***less*** sensory facilitation among the latter group. This result is at odds with most of the studies exploring ERPs in the social anxious population which indicate an enhanced sensory facilitation in socially anxious individuals as a manifestation of hypervigilance and excessive attention to potential threatening information (for a review see: Harrewijn et al., 2018). On the other hand, if socially anxious individuals rely more on social feedback, this decreased sensory facilitation could be explained precisely by this external influence. One possible interpretation is that when the feedback is given, it may lead socially anxious participants to pay less attention during the second colour presentation because superior weight is given to the majority's response, regardless of their own evaluation in the first presentation. In other words, when the response of the majority is given, socially anxious participants' lack of confidence in their own perception leads to decreased attention to the stimulus and therefore their response to the second stimulus will entirely depend on the social feedback. An alternate interpretation for the decreased P1 after the social feedback in the social anxious group could be the anticipation of the social task creating excessive internal attention and self-focus, thus, impairing processing of external stimuli (Clark & Wells, 1995; Deiters, Stevens, Hermann, & Gerlach, 2013; Sluis, Boschen, Neumann, & Murphy, 2017). In the present study, all participants were led to believe they would be giving an oral description/presentation at the end of the experiment in front of three psychologists. Indeed, it has been noted that the induction of speech anxiety in socially anxious subjects creates greater self-focus and task interference (Judah, Grant, & Carlisle, 2016). For example, Mellings and Alden (2000) observed that high socially anxious individuals recalled less environmental features than non-anxious individuals. Thus, these results are in line with Clark & Wells' (1995) cognitive model of social anxiety which predicts internally oriented attentional resources accompanied by attentional reduction to external social threats. After social feedback, N1 amplitudes were greater for both groups for ambiguous probes following disputed feedback, suggesting an endogenous attentional role of the N1 when a relevant discrimination is necessary to perform the task (Hopfinger & West, 2006). This was supported by the current study's findings, which showed an enhanced N1 for ambiguous probes following expressions of disgust compared to expressions of happiness in both groups of subjects. The current results corroborate N1's sensitivity to negative feedback but not its specificity to SAD as healthy subjects also showed defensive motivation when their response did not match the majority after social feedback. Moreover, findings in this study evidenced a decrease in N1 amplitudes for the three conditions among socially anxious individuals compared to controls, thus supporting Clark and Wells' (1995) cognitive model which proposes a reduction in attention to external stimuli due to excessive self-focusing in the socially anxious population.

The later LPP component confirms the reduction of effects in socially anxious participants. Again, this decreased sensory facilitation may reflect reduction of attention during the evaluation of the second stimulus, which depends entirely on the response of the majority and therefore on the social feedback. Moreover, Moser, Hajcak, Huppert, Foa, and Simons (2008) examined interpretation bias in social anxious individuals using ambiguous sentences and showed that later ERP components (P300, P400, P600) were diminished in social anxiety, which was mainly interpreted as a lack of positive bias towards positive sentence endings, despite a negative bias in behavioural measures. In a speech performance study, Heitmann et al. (2014) have shown that during the anticipation of a negative feedback, high socially anxious participants show deactivation of medial prefrontal brain areas, reflecting lower self-monitoring at this stage. Conversely, medial prefrontal and insular hyperactivation was observed during the processing of both negative and positive feedback, reflecting increased self-focus at this stage. Sachs et al. (2004) showed reduced P3 in social phobia in an oddball paradigm, reflecting a reduction in cognitive resources for information processing. Taken together, these results also suggest an increased self-focus in social situations and are consistent with our findings, with socially anxious participants showing decreased ERP amplitudes compared to control participants.

Although the aim of the current study was to investigate the effects of social anxiety on external non-social ambiguous stimuli within a social context, we also looked at the neural responses to social feedback, as ERPs have been widely used to examine processing of emotional faces in social anxiety. P1 amplitudes were not modulated by feedback valence. The effect was observed later when examining the face sensitivity N170. Findings showed greater N170 amplitudes for faces appearing after the ambiguous probes compared to distinct ones. Nevertheless, these effects were similar for both groups of subjects except that the differences were present in both hemispheres in the control group and only in the left hemisphere in the anxious group. The findings are in line with most studies on socially anxious individuals, showing no influence of social anxiety on N170 amplitudes (for a review, see Harrewijn, Schmidt, Westenberg, Tang, & van der Molen, 2017). Instead, these results suggest a bias in the general population reflecting heightened attention to faces following ambiguous probes. As a consequence, it seems reasonable to conclude that the structural analysis of faces in socially anxious subjects is not altered (e.g. Peschard, Philippot, Joassin, & Rossignol, 2013) but is rather lateralised to the left hemisphere, as has been previously shown (Bourne & Vladeanu, 2011). It might also be that disgusted faces do not elicit perceptive brain responses in socially anxious individuals as other negatively valenced facial expressions such as anger (Cui, Dong, & Zhang, 2021). Perception of disgust in this case can be analysed at the level of its significance rather than its perceptual processing and its effects may result in later responses such as the ones observed at the post-feedback stimulus re-evaluation stage.

The present study had some limitations that should be taken into consideration. First, the sample of socially anxious individuals was mainly constituted by female subjects. Thus, future studies should investigate these effects of anticipation on external stimuli in a male population. Second, in this study, all participants were told they would have an interview at the end of the experiment. It would be interesting to add two groups, socially anxious and non-socially anxious without inducing speech anxiety, to isolate the effect of performance anxiety induction. This would allow to investigate what is due to trait vs. state social anxiety in this context of social evaluation. Additionally, future studies examining later components of executive control may help to better understand individual differences in socially anxious individuals, as mechanism of inhibition, mental flexibility and emotional regulation, interact with threat anticipation and with visual processing of external cues. In the context of social evaluation in social anxiety, intolerance to uncertainty (IU; Carleton, Norton, & Asmundson, 2007a) and fear of evaluation (FNE; Carleton, Collimore, & Asmundson, 2007b) should also be evaluated in future studies.

From a clinical point of view, this investigation may provide further insight into the mechanisms and consequences of anticipatory processing in social anxiety and how they interact with impaired attention to external stimuli within a social context. Specifically, rather than focusing treatments on behavioural exposure of the anxiogenic social situation, treatments may want to consider the effects of imagery and interpretation of future social situations. Thus, clinical interventions should target negative imagery in anticipation of social events as well as unpleasant memory representations of social interactions and concentrate on imagery with rescripting techniques (Arntz, 2012) that focus on changing these unpleasant memories.

In conclusion, the present study provides behavioural and electrophysiological evidence for the role of anticipation of social situations among socially anxious individuals manifested by lower confidence ratings, higher number of revisions and a reduction in occipital and frontal networks which are thought to mediate early attention to external stimuli due to excessive self-focusing and self-consciousness. Moreover, findings provide further insight into the clinical implications of cognitive- behavioural therapy among socially anxious individuals.

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Declarations of interest

None.

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