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You don't like me, do you? Enhanced ERP responses to averted eye gaze in social anxiety

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ABSTRACT

Social anxiety is associated with an attentional bias toward angry and fearful faces, along with an enhanced processing of faces per se. However, little is known about the processing of gaze direction, a subtle but important social cue. Participants with high or low social anxiety (HSA/LSA) observed eye pairs with direct or averted gaze while subjective ratings and event-related potentials (ERPs) were measured. Behaviorally, all participants rated averted gaze as more unpleasant than direct gaze. Neurally, only HSA participants showed a trend for higher P100 amplitudes to averted gaze and significantly enhanced processing at late latencies (Late positive potential [LPP]), indicative of a specific processing bias for averted gaze. Furthermore, HSA individuals showed enhanced processing of both direct and averted gaze relative to the LSA group at intermediate latencies (Early posterior negativity [EPN]). Both general and specific attentional biases play a role in social anxiety. Averted gaze – a potential sign of disinterest – deserves more attention in the attentional bias literature.

1. Introduction

Current theories of social anxiety (Clark and Wells, 1995; Rapee and Heimberg, 1997) suggest that socially anxious individuals have an attentional bias for negative social cues, such as facial displays of anger, that could indicate social rejection or threat. This bias is thought to fuel negative self-beliefs (e.g. "Others dislike me"), thereby playing a key role in the initiation and maintenance of social fears. If socially anxious individuals subsequently avoid these cues (e.g. by reducing direct eye-contact), they might be perceived as less warm and interested by others (Clark and Wells, 1995), creating a vicious cycle.

The bulk of experimental research suggests a specific role for facial anger and other emotions in social anxiety (reviewed below). Less clear, however, is whether these negative attentional biases extend to more subtle social cues, such as *gaze direction*, which are much more common in every day life than open displays of anger but might still signal either social attention (direct gaze, Moukheiber et al., 2010; Schneier et al., 2011; Wieser et al., 2009) or disinterest/rejection (averted, Itier and Batty, 2009). Thus, eye gaze is more ambiguous when compared to distinct facial emotion and may therefore leave more room for anxiety specific interpretation and processing biases (e.g. Clark and Wells, 1995). In the following sections, we review available evidence regarding the behavioral (dot-probe) and neural (event related potentials [ERPs]) processing of emotional faces and eye gaze in socially anxious individuals.

1.1. Behavioral responses to faces and gaze in social anxiety

The most frequently employed approach for the study of attentional biases in social anxiety is the dot-probe paradigm. In this task, participants respond to a probe which – after a certain cue presentation time – replaces one of two lateral stimuli (e.g. faces). Speeding or slowing of this response is taken as evidence for spatial attention. While most studies which used dot-probe methods found a hyper vigilance (enhanced attention) for fearful and angry faces in social anxiety (e.g. Klumpp and Amir, 2009; Sposari and Rapee, 2007; Stevens et al., 2009), there is also research reporting either an avoidance of these faces (e.g. Gotlib et al., 2004; Pineles and Mineka, 2005) or an absence of group differences between socially anxious participants and controls (e.g. Chen et al., 2002). Since cue presentations times varied between these studies, their discrepant findings could partially be explained by assuming a *biphasic* response pattern: After an early enhanced negative attention to social threat follows a consecutive later avoidance of the feared stimuli (hyper vigilance – avoidance hypothesis; see also Heinrichs and Hofmann, 2001).

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A very common yet subtle facial cue is gaze direction (Adams et al., 2010; Emery, 2000; Henderson et al., 2005; Itier et al., 2007a,b; Maurage et al., 2011). In the context of neutral facial expressions, direct gaze signals social attention, which can be perceived threatening to social anxiety (Clark and Wells, 1995; Rapee and Heimberg, 1997), whereas averted gaze might signal disinterest (Itier and Batty, 2009). Several studies have been conducted on gaze and social anxiety, showing elevated fear ratings of eye-contact and avoidance of the eye region in social anxiety (e.g. Baker and Edelmann, 2002; Horley et al., 2003; Schneier et al., 2011). For example, in an eye-tracking study Horley et al. (2003) examined the number of fixations on pictures emotional and neutral faces in patients with social phobia and a healthy control group. As expected by the authors, social phobics showed fewer fixations on the eye-region of the presented faces, which was most pronounced for faces with an angry expression. However, a recent eye-tracking study by Wieser et al. (2009) on gaze processing in high socially anxious adults failed to confirm this. In their study, a sample of high (HSA) and low socially anxious (LSA) females watched animated neutral faces with either direct or indirect gaze. Surprisingly, the high anxious group did not avoid the eye-region of avatars with direct gaze more often than did low socially anxious females. Interestingly, both high and low socially anxious participants rated averted gaze as more unpleasant than direct gaze, pointing to the potential aversive quality of averted gaze when not paired with a negative facial emotion.

1.2. Brain responses to faces and gaze in social anxiety

To better understand the temporal dynamics of threat detection in social anxiety, researchers have used event-related potentials (ERPs), which due to their high temporal resolution allow detailed insights into early attentional and affective processing of facial information (e.g., Eimer and Holmes, 2007). Previous research has shown that ERPs to faces are modulated by gaze direction even at very early stages (e.g. 100 ms after stimulus onset), and may therefore serve as a highly sensitive indicator for the cortical processing of human gaze (Fichtenholtz et al., 2009; Itier et al., 2007a,b; Kloth and Schweinberger, 2010).

Several studies have investigated ERPs in socially anxious individuals to full faces (with direct gaze) and various emotional facial expressions. For example, Moser et al. (2008) presented HSA and LSA individuals with reassuring and threatening faces during a modified flanker task. While groups did not differ on behavioral measures, the HSA group showed larger parietal late positive potentials (LPPs) to threatening faces when compared to LSA individuals. Moser and colleagues interpret their findings as evidence for an enhanced processing of threatening faces in high social anxiety. This interpretation is supported by the results of other ERP studies on face processing in socially anxious samples (Kolassa and Miltner, 2006; Rossignol et al., 2007). However, there is also evidence for a priorized processing of faces in HSA individuals irrespective of expression. For example, Mühlberger et al. (2009) recently assessed ERPs elicited by both natural and artificial faces with fearful, angry, happy as well as neutral expressions in a sample of HSA and LSA participants. Over the right hemisphere, HSA individuals showed an enhanced P100 to all faces, possibly indicating very early attentional processing (cf. Luck et al., 2000; Mangun, 1995). Further, the LPP amplitudes discriminated between neutral and emotional faces in LSA individuals, while this was not the case in high socially anxious individuals, possibly due to their generally increased responding. Similar results are reported by Kolassa et al. (2007) who found enlarged P100 amplitudes in social phobics to emotional faces regardless of expression. Thus, there is evidence for specific biases (enhanced responses to certain expressions) as well as for generalized biases (enhanced responses to faces per se) in social anxiety.

Table 1
Participant characteristics.

Q3

	HSA $n = 26$	LSA $n = 25$	p-value
Age	20.5 (2.87)	21.5 (2.67)	.266
Gender (m/f)	13/13	14/11	.668
Ethnicity (% Caucasian)	68%	60%	.213
BFNE	41.7 (5.45)	24.2 (6.79)	<.001*
BDI-II	9.53 (6.77)	5.56 (5.85)	.034*
STAI – Trait	44.3 (10.8)	33.0 (7.89)	.001*
STAI – State	36.0 (7.21)	31.7 (5.84)	.027*

Note. BFNE, Brief Fear of Negative Evaluation Questionnaire (Carleton et al., 2006); BDI-II, Beck Depression Inventory (Beck et al., 1996); STAI, State-Trait Anxiety Inventory (Spielberger et al., 1970).

1.3. The present study

The goal of the current study was to examine early attentional/emotional processing of direct and averted gaze in the absence of disambiguating facial expression in relation to social anxiety. HSA and LSA participants were exposed to images of isolated eye pairs with either direct or averted gaze while subjective ratings and ERPs were obtained. In line with previous findings from behavioral and eye-tracking studies on gaze processing and ERP studies on faces in social anxiety (Horley et al., 2003; Kolassa et al., 2007; Kolassa and Miltner, 2006; Moser et al., 2008; Moukheiber et al., 2010; Schneier et al., 2011) our hypotheses were the following. (1) Behaviorally, HSA participants will rate direct gaze as more unpleasant than LSA participants. (2) Neurally, on ERPs (P100; N170; EPN; LPP), HSA individuals will show an enhanced processing of direct eye-gaze and/or a generally enhanced processing of all gaze stimuli when compared to the LSA Group. We also assessed gaze effects on early posterior negativity (EPN), which may be particularly sensitive for an enhanced face processing in social anxiety (e.g. Blechert et al., 2012; Mühlberger et al., 2009). Since there have been reports of sex differences in responding (e.g. Bradley et al., 2001), we also assessed effects of participant and target sex.

2. Method

2.1. Participants

Participants were 55 (28 female) undergraduates from two West Coast universities in the United States who had normal or corrected to normal vision and who participated for course credit. Participants were recruited through a screening procedure to obtain a sample with a wide range of levels of social anxiety along an overrepresentation of extreme groups (high vs. low). None of the participants reported a history of a psychiatric or neurological disorders. Participants were split into two groups using their scores on the Brief Fear of Negative Evaluation Questionnaire (BFNE; Median: 33) and were assigned either to the low social anxiety (LSA; $n = 25$) or the high social anxiety group (HSA; $n = 26$). Two participants were excluded because their BFNE scores fell on the median. Details on the demographic and psychometric characteristics of the sample can be found in Table 1.

2.2. Measures

The *Brief Fear of Negative Evaluation* questionnaire (BFNE; Carleton et al., 2006) is a self-report measure assessing fear and worry of negative evaluation by others (e.g. "I am usually worried about what kind of impression I make"), the main diagnostic criterion for social phobia, and is composed of 12 items which are rated on a Likert Scale ranging from 1 ("Not at all") to 5 ("Extremely"). The BFNE Scale successfully discriminates social anxious from non-anxious participants, has an excellent reliability, and shows high correlations with other measures of social anxiety (Carleton et al., 2007; Wieser et al., 2009). We used the BFNE to split participants into HSA and LSA groups.

To more completely characterize participants, we also administered two other measures. The *Beck Depression Inventory* (BDI-II: Beck et al., 1996) is a 21-item self-report measure of depressive symptoms over the preceding two weeks (e.g. "I am sad all the time"). Items are rated on a 4-point Likert-type scale ranging from 0 to 3, based on severity of each item. It has a good internal consistency and concurrent

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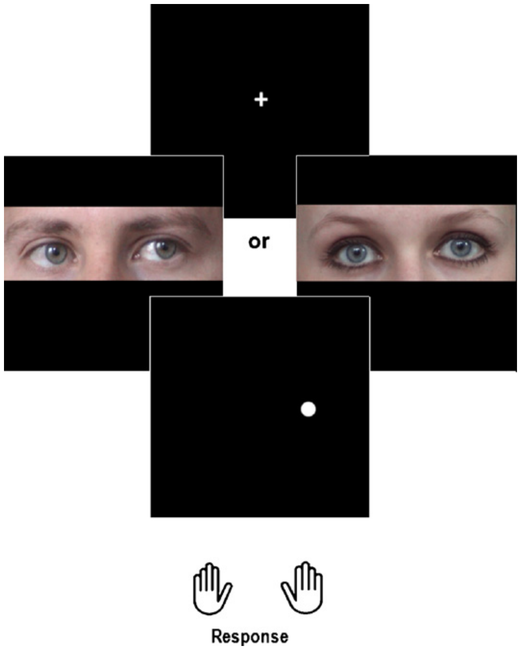

Fig. 1. Example for one direct and one averted gaze trial. After picture offset, participants had to report the location of the white dot as fast and accurately as possible with either right or left hand.

validity with other measures of depression (Beck et al., 1996; Storch et al., 2004). The *Stait-Trait Anxiety Inventory* (STAI; state and trait; Spielberger et al., 1970) is a 20-item scale that measures the stable (trait) propensity to experience anxiety and the tendency to perceive stressful situations as threatening, whereas the STAI-state is a 20-item scale that measures the actual anxiety (e.g. "I feel tense"). Items are rated on a Likert Scale ranging from 1 ("Not at all") to 4 ("Very much so"). Both scales show good to excellent psychometric properties (Spielberger and Diaz-Guerrero, 1983).

In the current sample, all measures showed good to excellent internal consistency (alpha = .77–.90).

2.3. Procedure

For EEG recording, participants were seated in a comfortable chair in a sound-attenuated, dimly lit room, and were instructed that they would be presented with a sequence of images and videos, which they had to watch attentively.[1] The experiment consisted of 64 trials during which a neutral-valenced photograph of either direct or 30° left/right averted gaze was presented on a computer monitor centered on the screen. In a pilot study, all pictures were rated as showing a neutral facial expression. The total stimulus set, created by us, consisted of frontal photographs of the eye region (see Fig. 1) of 32 individuals (16 males and 16 females; 18–55 years of age). Stimuli were presented in a randomized order for 3000 ms each with a variable inter-trail interval of 800–1200 ms, during which a central fixation cross was presented. To ensure that participants were attentive throughout the experiment, and did not avert their gaze, a probe (white dot) was presented after each trail, replacing either the right or left eye of the model. Participants were instructed to report the location of the probe (right or left) as quickly and accurately as possible by pressing a corresponding key with either left or right hand. There was no significant difference between the groups regarding manual laterality. After the end of the session, participants reviewed all stimuli and gave pleasantness ratings on an on-screen 100 mm VAS (0 – *pleasant* to *unpleasant* – 100) before electrode removal and debriefing.

2.4. EEG recording and analyses

EEG recordings were made using Syn Amps amplifiers, and digitized with Scan 4.3 software (Neuroscan, Inc., Sterling, VA, USA). EEG recordings were obtained with standard Ag/AgCl electrodes from 42 sites on the scalp, based on the 10–20 system. During recording, AFz served as the ground and Pz as the online reference. The electro-oculogram (EOG) reflecting eye-blinks and eye-movements was recorded from sites 2 cm below and above the right eye.

During recording, the EEG signal was sampled at a rate of 500 Hz and band-pass filtered from 0.05 Hz to 100 Hz. Impedance levels at all channels were kept below 5 kΩ. Offline, pre-processing was conducted using Brain Vision Analyzer 2.0.1 (Brain Products GmbH, Gilching, Germany). The EEG raw data were filtered (low pass = 40 HZ, 48 dB/oct), segmented (200 ms pre- to 1000 ms post-stimulus), and corrected for blinks and eye-movements using Independent Component Analysis (Jung et al., 2000). Trials with amplitude deviations ±150 μV were rejected. The number of rejected epochs was generally low[2] (3.21%) and did not differ by group or condition, *ps* > .657. Epochs were baseline corrected to the 200 ms pre-stimulus baseline, and referenced to an average reference. Finally all EEG epochs were averaged for each subject, condition, and electrode.

For early and well established ERP components (P100, N170), the following electrode positions and time windows were chosen according to previous studies (Kolassa et al., 2007; Mühlberger et al., 2009; Wieser et al., 2010): P100 amplitudes at O1, O2 (70–140 ms) and N170 at P7, P8 (140–190 ms). Middle component EPN was analyzed on leads P7, P8, O1, and O2 (cf. Mühlberger et al., 2009; Wieser et al., 2010) during a time window of 200–250 ms post-stimulus onset (according to visual inspection; see Fig. 2). The later component LPP was analyzed within a time frame of 450–550 ms post stimulus onset (cf. Kolassa et al., 2007) at POz, which was the lead with the highest mean LPP amplitude (c.f. Moser et al., 2008). For all analyses, we calculated the average ERP amplitude (μV) within the defined interval.

The behavioral and ERP data were analyzed with repeated measures ANOVAs with the between subject factors Group (HSA, LSA), and Participant-Gender (male, female), and the within-participant factors Gaze direction (direct, averted), Stimulus-Gender (male, female), and Laterality (Laterality was included only for P100, N170, and EPN data, but not for ratings and LPP data). For the sake of brevity, we report effects of participant-gender, stimulus-gender, and laterality only when they interacted with group. Simple post hoc comparisons were used to localize significant interactions. Statistical analyses were run using Statistica software (StatSoft, Inc., Tulsa, OK, USA) with significance level set at alpha = .05. Partial eta square (η_p^2) is presented as effect size measure.

3. Results

3.1. Preliminary analyses

As presented in Table 1, groups did not differ in age, sex, or ethnicity.[3] As expected, HSA participants had higher scores on BFNE, BDI-II, and state and trait scales of the STAI. Rating data can be found in Table 2. To control gaze avoidance and to ensure comparable fixation in both groups, participants had to report the location of a probe after stimulus offset. Neither reaction times nor the number of correct responses differed significantly by Group or Gaze direction, and there was no Group × Gaze direction interaction on these measures, all *F*s < 2.86, *ps* > .097.

3.2. Behavioral ratings

A 2 (Group: HSA; LSA) × 2 (Gaze-direction: direct; averted) × 2 (Stimulus-Gender) × 2 (Participant-Gender) mixed ANOVA with repeated measures on Gaze-direction and Stimulus-Gender revealed a Gaze main effect: averted gaze was rated as more unpleasant than direct gaze,[4] $F(1,35) = 6.17$, $p = .018$, $\eta_p^2 = .150$. This was most pronounced for female stimuli when rated by HSA females, $F(1,35) = 12.1$, $p = .001$, $\eta_p^2 = .257$, and by LSA males, $F(1,35) = 5.91$, $p = .022$, $\eta_p^2 = .139$, indicated by a significant Group × Gaze-direction × Stimulus-Gender × Participant-Gender 4-way interaction, $F(1,35) = 4.91$, $p = .033$, $\eta_p^2 = .123$ (Table 2). All other *F*s < 3.45, *ps* > .071.

[1] An equal number of gaze-videos (direct and averted gaze) was presented (3000 ms) intermixed with the gaze pictures. However due to variability in onsets, respective ERP data could not be analyzed.

[2] Two HSA participants had to be excluded from analyses due to poor EEG recording quality (more than 50% rejected epochs).

[3] Cultural studies suggest that visual face processing may differ between Western and East-Asian participants (see Jack et al., 2012). However, our study included only a few participants with an Asian ethnic background (HSA = 3; LSA = 2).

[4] Due to a technical error, rating data were available only from 39 participants (HSA: 19; LSA: 20).

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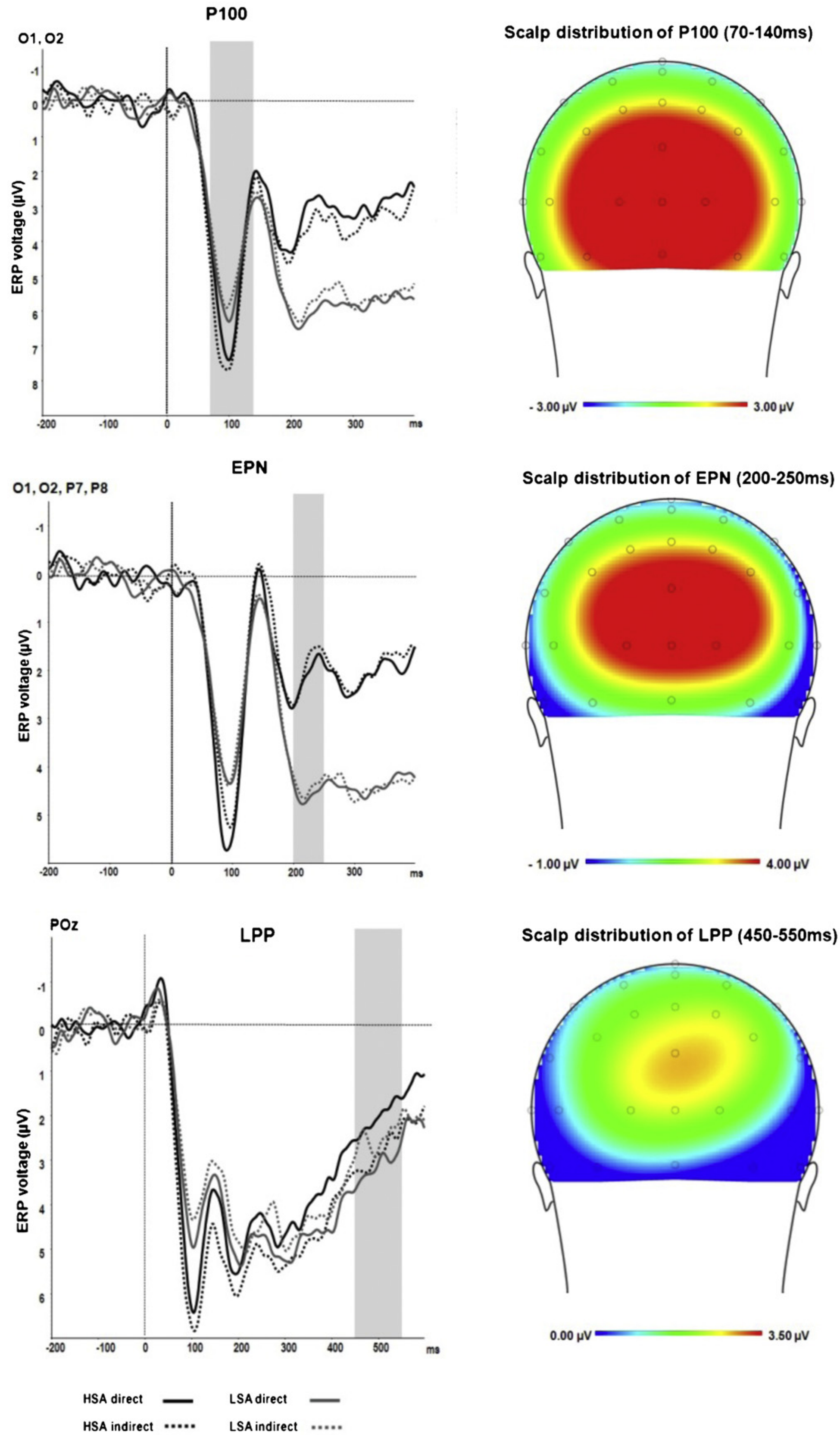

Fig. 2. Grand mean ERPs (P100, EPN, and LPP) to direct and averted gaze in HSA and LSA group and scalp distributions.

Table 2
Subjective valence ratings (means and standard errors) as a function of gaze direction, gender, and group.

	HSA ($n = 19$)				LSA ($n = 20$)			
	Male direct	Male averted	Female direct	Female averted	Male direct	Male averted	Female direct	Female averted
Subjective ratings (0–100)								
Male participants	53.8 (3.43)	58.4 (4.53)	46.5 (3.99)	49.5 (3.79)	51.1 (4.43)	52.9 (5.14)	44.3 (4.20)	49.3 (5.12)
Female participants	48.2 (3.84)	44.7 (4.12)	36.6 (2.63)	43.12 (3.25)	48.0 (2.71)	46.0 (2.53)	41.6 (3.06)	40.1 (3.07)

Note. HSA, high social anxiety group; LSA, low social anxiety group.

3.3. Brain responses

P100: The 2 (Group) × 2 (Laterality: O1; O2) × 2 (Gaze-direction) × 2 (Stimulus-Gender) × 2 (Participant-Gender) mixed ANOVA showed a significant Group × Gaze direction interaction, $F(1,47) = 4.66$, $p = .036$, $\eta_p^2 = .090$, but no main effect of Group, $F(1,47) = 1.76$, $p = .188$. A post hoc test showed a trend for the HSA group's P100 amplitudes to be more positive for averted gaze than for direct gaze ($M_{direct} = 5.38$, $SEM_{direct} = 0.64$; $M_{averted} = 5.92$, $SEM_{averted} = 0.68$), $F(1,47) = 3.93$, $p = .053$, $\eta_p^2 = .070$, while there was no such effect in LSA participants ($M_{direct} = 4.88$, $SEM_{direct} = 0.62$; $M_{averted} = 4.58$, $SEM_{averted} = 0.55$), $F(1,47) = 1.73$, $p = .284$. All other main effects and interactions were non-significant, $Fs < 3.64$, $ps > .062$.

N170: The repeated measures ANOVA showed no significant main effects or interactions, $Fs < 1.71$, $ps > .197$.

EPN: A similarly structured ANOVA revealed that HSA participants showed significantly higher EPN amplitudes compared to LSA participants, Group main effect: $F(1,47) = 8.56$, $p = .005$, $\eta_p^2 = .154$, irrespective of gaze direction, Group × Gaze-direction: $F(1,47) = 1.85$, $p = .265$. This main effect was further qualified by a significant Group × Gaze-direction × Participant-Gender interaction, $F(1,47) = 7.12$, $p = .010$, $\eta_p^2 = .132$, all other $Fs < 2.22$, $ps > .142$. Post hoc simple effect analyses indicated that male LSA participants further showed a modulation by gaze direction: EPN amplitudes to averted gaze were more negative, when compared to direct gaze, $F(1,47) = 4.12$, $p = .047$, $\eta_p^2 = .080$ (see Table 3 and Fig. 2).

LPP: For LPP amplitudes there was a significant interaction of Group × Gaze-direction, $F(1,47) = 7.22$, $p = .010$, $\eta_p^2 = .133$, which was due to higher LPP amplitudes to averted than to direct gaze in HSA ($M_{direct} = 2.04$, $SEM_{direct} = 0.62$; $M_{averted} = 2.87$, $SEM_{averted} = 0.73$), $F(1,47) = 4.25$, $p = .044$, $\eta_p^2 = .081$, but not in LSA participants ($M_{direct} = 3.13$, $SEM_{direct} = 0.59$; $M_{averted} = 2.50$, $SEM_{averted} = 0.51$), $F(1,47) = 3.04$, $p = .087$, all other $Fs < 2.09$, $ps > .155$.

4. Discussion

To our knowledge, this is the first study investigating the differential behavioral and electro-cortical processing of direct vs. indirect gaze in the absence of disambiguating facial emotion, a subtle and highly common social cue, in high vs. low socially anxious individuals. *Behaviorally*, we had predicted more unpleasant ratings for direct gaze only in the HSA group. Contrary to this expectation, we found that *averted* gaze was experienced as more unpleasant across both groups (an effect which was further modulated by gender and anxiety). *Neurally*, we expected that only the HSA but not the LSA group would show an enhanced processing (attentional bias) of direct gaze as indicated by higher ERP amplitudes to direct when compared to averted gaze. Contrary to this hypothesis, the socially anxious group showed a trend toward higher P100 amplitudes and significantly higher LPP amplitudes to *averted* gaze relative to direct gaze while no such modulation was found in LSA individuals. We had also predicted that when compared to LSA participants, the HSA group would show a generally enhanced processing of gaze irrespective of gaze direction, as indicated by higher amplitudes of attention-related ERP. Partially confirming this assumption, the high anxious group showed higher EPN amplitudes for both direct and averted gaze, but no such group main effects were found on P100, N170, and LPP components.

4.1. Attentional bias for averted gaze in high socially anxious participants

In the context of ambiguous facial cues, both HSA and LSA participants rate *averted* gaze as more unpleasant than *direct* gaze. This contradicts previous empirical findings that socially anxious individuals report elevated levels of fear of direct eye-contact with others, and avoid direct eye-contact (Horley et al., 2003; Moukheiber et al., 2010; Schneier et al., 2011). This behavioral pattern was also reflected in neural responding in HSA individuals where early (P100, statistical trend) and late (LPP) attention related ERPs were enhanced for *averted* gaze. Neural responses suggest a facilitated processing of negatively evaluated stimuli both at very early attentional processing (P100; Luck et al., 2000; Mangun, 1995) and again during more detailed and sustained attentional analysis (LPP; Sabatinelli et al., 2007).

Why was averted gaze – and not direct gaze – interpreted negatively? One possible explanation could be that direct gaze is only threatening when paired with a negative facial expression (Adams et al., 2003; Roelofs et al., 2010), whereas in the context of neutral facial expression averted gaze is rather perceived as sign of disinterest. Regarding direct gaze and negative facial expression, a closer look at the eye tracking literature seems to support this: Horley et al. (2003) found that social phobic patients avoided the eye-region of faces only in the context of angry expressions but tended to showed even more fixations on the eye-region in the context of neutral faces when compared to controls. Similarly, in a recent study by Moukheiber et al. (2010), social phobics made fewer fixations and had a shorter dwell time on the eye-region of emotional but not on neutral faces. Gaze avoidance was again most pronounced for faces with negative emotions (e.g. anger, disgust). Thus, is its conceivable that direct gaze is only feared and avoided in socially anxious individuals when it is paired with negative emotions such as anger, indicating elevated threat of negative evaluation (Roelofs et al., 2010).

If direct gaze in the context of neutral facial expression was not threatening, what could drive the processing advantage of averted gaze in social anxiety? It has been suggested that averted gaze signals disinterest (Itier and Batty, 2009; Strick et al., 2008). Supporting this interpretation, previous research found that averted gaze but not direct gaze (both in the context of neutral expressions) activates the motivational avoidance system (Hietanen et al., 2008; Ponkanen et al., 2011). Similarly, Wieser et al. (2009) found that both socially anxious and non-anxious females rated neutral faces of averted eye-gaze as more unpleasant that direct gaze. Clearly, future studies will be needed to experimentally cross facial expression with gaze direction in the context of social anxiety to clarify this issue.

A possible alternative explanation for the higher LPPs to averted gaze in the HSA group relates regulatory influences on *direct* gaze. A growing number of studies have documented modulations of

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Table 3
EPN amplitudes (means and standard errors in μV) to direct and averted gaze as a function of participant gender and group.

	HSA (n = 24)		LSA (n = 25)	
	Direct gaze	Averted gaze	Direct gaze	Averted gaze
EPN (200–250 ms)				
O1, O2, P7, P8				
Male participants	2.73 (1.02)	3.41 (1.03)	5.68 (1.16)	5.09 (1.33)
Female participants	1.22 (0.71)	0.66 (0.68)	4.32 (0.83)	4.36 (0.88)

Note. EPN, early posterior negativity; HSA, high social anxiety group; LSA, low social anxiety group.

the LPP and earlier components by emotion regulation strategies. Accordingly, direct gaze might have been spontaneously down-regulated or avoided (see also Gyurak et al., 2011). Reappraisal (e.g. by strategies like: "this is not a real person – this is not relevant to me") or distraction (generation of unrelated thoughts) could have led to such changes, particularly on the LPP (Blechert et al., 2012; Hajcak et al., 2010; Thiruchselvam et al., 2011). It is possible that direct gaze was avoided or downregulated by socially anxious individuals, probably because with longer presentation duration it may have been perceived as an unpleasant interpersonal stare and awkward interpersonal attention (see also Fig. 2). This would again fit into Wieser et al.'s (2009) results that, while averted gaze was rated as more unpleasant than direct gaze across groups, direct gaze still elicited a stronger heart rate acceleration in the HSA group. This regulation approach, however, does not explain the trend toward a significant Group × Gaze interaction on the P100 since this very early component is rather increased than reduced by reappraisal (Blechert et al., 2012). An interesting future direction may be how the processing of eye-gaze could be modulated by different strategies of emotion regulation.

4.2. Enhanced processing of the eye region in high socially anxious individuals?

EPN amplitudes in socially anxious individuals were enhanced to eye pairs regardless of gaze direction, indicating a stronger attentional processing at an intermediate attentional processing step. A possible interpretation of this result could be that HSA participants show a generally enhanced processing of the eye-region independent of gaze direction.

When considering this interpretation, one has to take into account that we did not include a neutral non-social control condition, and it remains possible that the higher EPN amplitudes in our HSA group reflect rather an enhanced processing of generally neutral than neutral *social* stimuli. Still the interpretation of a priorized eye-region processing would correspond well with most literature in the social anxiety field: the EPN to angry faces was recently found to be increased by high *state* social anxiety, triggered by the anticipation of a social stressor (Wieser et al., 2010). Similar processes might occur here, where *trait* socially anxious individuals might reveal generalized negative expectancies with regard to any social stimulus. Generalized hyper-responding to social stimuli in social anxiety has also been reported in other EEG and fMRI studies (e.g. Evans et al., 2008; Kolassa et al., 2007; Kolassa and Miltner, 2006; Moser et al., 2008; Phan et al., 2006; Straube et al., 2004). If we believe that our EPN results reflect a general enhanced processing of social information, they extend previous study results by showing that the mere presentation of eye pairs – in the absence of any other facial and emotional cues – may be sufficient to uncover abnormal attention processing in social anxiety. This would underline the severity of an impaired processing of social information in social anxiety.

4.3. Limitations and future directions

Several limitations of the present study should be acknowledged. *First*, since we tested a subclinical sample, the results cannot be extended to social anxiety disorder without further research. In addition, the number of trials per condition was relatively small in our study, and the P100 effect in our HSA group was only significant on a trend level. Hence this effect needs replication to evaluate its reliability (e.g. with a higher number of trials). *Second*, we cannot rule out the possibility that socially anxious individuals displayed subtle forms of avoidance, e.g. by slightly shifting their gaze away from the eye pairs in one of the two conditions. However, Wieser et al. (2009) did not find indications of gaze avoidance in this population and our attentional performance measure (probe detection after gaze stimulus) did not show performance differences between the groups. Nevertheless, combined ERP and eye-tracking research would be desirable. *Third*, we used pictures of eye-gaze without a real life social interaction and future research should vary stimulus type (real person, picture; see also Hietanen et al., 2008; Ponkanen et al., 2011) and gaze (direct, averted) in individuals with various degrees of social anxiety to clarify this issue and might combine the features of gaze direction and facial expression to assess their additive or interactive effects (Adams et al., 2003; Langton et al., 2000; Roelofs et al., 2010). Further, gender played a moderating role for valence ratings, both on the participant and on the stimulus side. In our study, female participants rated direct female gaze as most pleasant while male direct gaze was evaluated as most unpleasant. This fits into previous results indicating, that direct male gaze may be perceived as more threatening by females – probably because it is interpreted as interpersonal threat/aggression – than female direct gaze (e.g. Wieser et al., 2009). Hence, evaluative biases may vary depending on gender of the interaction partners and highlights the complexity of social interaction research and the need for more research.

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