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How does gaze direction affect facial processing in social anxiety? —An ERP study

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A R T I C L E I N F O

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A B S T R A C T

Previous behavioral studies have demonstrated an effect of eye gaze direction on the processing of emotional expressions in adults with social anxiety. However, specific brain responses to the interaction between gaze direction and facial expressions in social anxiety remain unclear. The present study aimed to explore the time course of such interaction using event-related potentials (ERPs) in participants with social anxiety. High socially anxious individuals and low socially anxious individuals were asked to identify the gender of angry or neutral faces with direct or averted gaze while their behavioral performance and electrophysiological data were monitored. We found that identification of angry faces with direct but not averted gaze elicited larger N2 amplitude in high socially anxious individuals compared to low socially anxious individuals, while identification of neutral faces did not produce any gaze modulation effect. Moreover, the N2 was correlated with increased anxiety severity upon exposure to angry faces with direct gaze. Therefore, our results suggest that gaze direction modulates the processing of threatening faces in social anxiety. The N2 component elicited by angry faces with direct gaze could be a state-dependent biomarker of social anxiety and may be an important reference biomarker for social anxiety diagnosis and intervention.

1. Introduction

Cognitive models of social anxiety suggest that threat-related information processing bias plays a critical role in the development and maintenance of subclinical social anxiety and social anxiety disorder (Bar-Haim et al., 2007; Kolassa and Miltner, 2006). A large number of studies demonstrated that individuals with social anxiety tend to show cognitive bias towards threatening information, potentially leading to increased threat detection or anxious experiences (Schultz and Heimberg, 2008; van Peer et al., 2010). Threatening faces (e.g. angry faces) are considered a signal of social threat conveying dislike and hostility. In a dot-probe task in conjunction with high-density event-related potentials (ERPs), Mueller et al. (2009) found that participants with social anxiety disorder (SAD) showed potentiated P1 amplitudes in response to angry faces, providing electrophysiological support for attentional bias to angry faces in SAD. Neuroimaging studies suggested that the degree of amygdala activation upon exposure to threatening faces can be linked to the severity of social anxiety symptoms (Killgore and Yurgelun-Todd, 2005; Phan et al., 2006; Yoon et al., 2007).

Gaze direction displayed by eyes, which conveys information about the focus of attention and future intentions, is another essential signal for social communication in.

our daily life. Previous studies have reported inconsistent results in processing gaze direction in social anxiety. Wieser et al. (2009) found that high socially anxious women showed a longer fixation time to the eye region compared with medium and low socially anxious women in an eye-tracking study, indicative of no tendency to avoid direct gaze. However, a recent ERP study (Schmitz et al., 2012) reported that averted gaze elicited higher P100 and LPP amplitudes compared to

Abbreviations: SAD, Social anxiety disorder; ERPs, event-related potentials; HSA, high socially anxious individuals; LSA, low socially anxious individuals; ERs, mean error rates; RTs, reaction times; LSAS, Liebowitz Social Anxiety Scale; HVOT, Hooper Visual Organization Test; EEG, Electroencephalogram; VEOG, vertical electro-oculogram; HEOG, horizontal electro-oculogram; ABM, attention bias modification

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direct gaze in high socially anxious participants.

A growing body of evidence suggests that gaze direction modulates the processing of facial expressions. Angry faces were found to be recognized more quickly when coupled with direct gaze compared to averted gaze, while the detection of fearful faces showed the opposite pattern (Adams et al., 2003). Graham and LaBar (2007) found that coupling angry faces with averted gaze resulted in slower processing, thus allowing gaze to interfere with emotion judgments. These results were replicated by N'Diaye, Sander, and Vuilleumier (N'Diaye et al., 2009) using mild-intensity expressions. Moreover, it was suggested that high trait-anxious participants show enhanced orienting toward fearful faces with averted gaze relative to happy and angry faces (Fox et al., 2007). Based on ERP results, Striano et al. (2006) reported that gaze direction influenced the ERP in response to angry faces in 4-month-old infants. Akechi et al. (2010) also reported that angry faces with direct gaze and fearful faces with averted gaze were recognized more accurately and elicited larger N170 than angry faces with averted gaze and fearful faces with direct gaze in typically developing children. These findings were supported by neuroimaging studies investigating the neural processing of integrating facial expressions and eye gaze directions. Sato et al. (2010) reported enhanced activity in the amygdala in response to angry and happy dynamic facial expressions with direct gaze compared to averted gaze. Another study (Hadjikhani et al., 2008) found that fearful faces with averted but not direct gaze elicited increased activation in the amygdala. Aiming at providing a potential explanation for gaze direction dependent processing of facial expressions, Adams and Kleck (Adams et al., 2003; Adams and Kleck, 2005) suggested that angry faces coupled with direct gaze are recognized more quickly than those with averted gaze due to the indication of a clear threat directed at the observer. In contrast, angry faces coupled with averted gaze could indicate an ambiguous threat, signaling a potential environmental threat.

To our knowledge, less is known about the influence of gaze direction on the processing of threatening faces in social anxiety. Roelofs et al. (2010) administered an Approach-Avoidance Task to investigate the effects of eye gaze direction on behavioral responses elicited by emotional faces. The authors reported that high socially anxious individuals were faster in avoiding angry faces with direct but not averted gaze, reflected by shorter reaction times for avoidance (pushing a joystick, making the picture shrink) than approach (pulling a joystick, making the picture grow in size). Based on aforementioned studies, we speculate that gaze modulation might play an important role in the processing of threatening faces in social anxiety and might foster an understanding of the psychopathology of anxiety.

The aim of the present study was to investigate brain responses upon interaction between gaze direction and facial expression in a sample of undergraduate subclinical social anxiety subjects using the ERP method. Subjects were required to complete a gender identification task (Swartz et al., 2013) while ERPs of the facial stimuli were recorded during this discrimination task. Given that various ERP components seem to be involved in processing facial expression and eye gaze (Kolassa and Miltner, 2006; Mueller et al., 2009), we chose a subset containing P1, N170 and N2 components that were in line with previous findings. P1 is sensitive to the physical features of a stimulus at the early attention stage and SA individuals were reported to display enhanced P1 toward angry–neutral compared to happy–neutral face-pairs (Mueller et al., 2009). Previous studies also demonstrated that P1 is affected by gaze direction in typically developing children and SAD patients (Akechi et al., 2010; Schmitz et al., 2012). On the other hand, N170 is a face-specific ERP component sensitive to emotional expressions. Kolassa and Miltner (2006) demonstrated that negative expressions elicited a larger occipito-temporal N170 during an emotion identification task in individuals with social phobia. Moreover, N170 is sensitive to the interaction of gaze direction and facial expression (Akechi et al., 2010). The face-specific N2 is associated with selective attention, with higher amplitude indicating greater attention (Derks et al., 2015; Engell and McCarthy, 2014). Yuan et al. found that high socially anxious subjects generated a higher P2-N2 peak-to-peak value than low socially anxious subjects while viewing faces (Yuan et al., 2014).

Based on theoretical work and empirical findings reviewed above, we hypothesized that high socially anxious individuals would exhibit generally enhanced event-related potentials (P1; N170; N2) compared to low socially anxious individuals. Furthermore, we expected increased N170 and N2 modulations in high socially anxious individuals only when processing angry faces with direct gaze. For the behavioral data, mean error rates (ERs) and reaction times (RTs) in response to the stimulus were assessed, we predicted that high socially anxious individuals would react faster to angry faces than to neutral faces (Akechi et al., 2010; Swartz et al., 2013).

2. Methods

2.1. Participants

We asked 1028 students at the Anhui Medical University to complete the Chinese version of the Liebowitz Social Anxiety Scale (LSAS) (He and Zhang, 2004). The LSAS is a 24-item scale that is scored on a 0–3 scale. Participants were asked to rate both fear and avoidance of social situations during the preceding week. The Chinese version of the LSAS has been validated for high internal consistency (Cronbach's α=0.97) and good test-retest reliability (r =0.94). Twenty-three students (14 females, mean LSAS score =69.70, SD =10.39) from the top 10% of the LSAS distribution comprised the high socially anxious group and twenty-three students (13 females, mean LSAS score =13.65, SD =5.56) from the bottom 10% of the LSAS distribution comprised the low socially anxious group. Details on the demographic and psychometric characteristics of the sample population are displayed in Table 1.

The cognitive evaluation was performed using the Stroop Test and the Hooper Visual Organization Test (HVOT) (Azambuja et al., 2012). The HVOT is a 30-item screening instrument that measures visual-spatial organizational ability. It consists of line drawings of simple objects that have been cut into pieces and rearranged, such as in a puzzle. The examinee's task is to name what each object would be if the pieces were put back together. All of the participants were screened for any history of mental disorders or neurological disorders. The study was executed in agreement with the Declaration of Helsinki and approved by the Ethics Committee of Anhui Medical University. Informed consent forms were signed by all subjects.

2.2. Stimuli and apparatus

The facial stimuli were 10 native models (5 females and 5 males) selected from the native Chinese Facial Affective Picture System (Luo et al., 2010). The faces in the system were assessed by 100 college

Table 1
Participant characteristics.

	HSA (n =23)	LSA (n =23)	*p*-value
Sex (males/female)	9/14	10/13	0.77
Age (years)	19.39(1.03)	19.87(1.32)	0.37
Handedness (R/L)	23/0	23/0	1.00
HAMA	3.17(3.06)	1.04(1.42)	0.004
HAMD	2.61(2.65)	0.87(1.32)	0.003
LSAS score (total)	68.70(10.39)	13.65(5.56)	0.008
Stroop test	7.58(2.99)	7.38(2.96)	0.87
HVOT	23.07(2.24)	22.70(3.07)	0.11

Note: HSA, High socially anxious; LSA, low socially anxious; LSAS, Liebowitz Social Anxiety Scale; HAMA, Hamilton Anxiety Rating Scale; HAMD, Hamilton Depression Rating Scale; HVOT, Hooper Visual Organization Test.