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Time course of attentional bias in social anxiety: the effects of spatial frequencies and individual threats

Abstract

Hypervigilance and attentional bias to threat faces with low-spatial-frequency (LSF) information have been found in individuals with social anxiety. The vigilance–avoidance hypothesis posits that socially anxious individuals exhibit initial vigilance and later avoidance to threatening cues. However, the temporal dynamics of these two processes in response to various LSF threats in social anxiety remain unclear. In the current study, we presented faces containing anger, disgust, and fear in high and low spatial frequencies and compared the neural correlates of sensory perception and attention in individuals with high versus low social anxiety (HSA/LSA, $n = 24$). A visual search task was used to investigate the attentional effects of threats and spatial frequencies, and event-related potentials (ERPs), particularly, the visual components of P1 and P250, were measured to index visual perceptual and attentional processes, respectively. We found that HSA individuals showed pronounced P1 and reduced P250 to LSF (vs. HSF) faces, regardless of emotion type, suggesting a general pattern of initial vigilance and later avoidance to LSF faces in social anxiety. Furthermore, while LSA individuals showed enhanced P250 to both fear and disgust (vs. neutral) faces, HSA individuals showed pronounced P250 to disgust faces alone. Our results thus elucidate the temporal profile of early vigilance and later avoidance in social anxiety, highlighting its broad implication for all faces and predominance in the low spatial frequency. Considering individual threats, our results demonstrate specific attentional avoidance of fear faces in social anxiety.

Keywords: ERPs; Threat; Social Anxiety; Perception and attention bias

1 Introduction

Social anxiety disorder (SAD) is a disorder characterized by exaggerated fear of social or performance situations (Rapee & Spence, 2004). Individuals with SAD have been found to show hypervigilance or attentional bias to threat faces (e.g., Harrewijn, Schmidt, Westenberg, Tang, & Mjw, 2017). For example, enhanced activation of the amygdala (Evans et al., 2008; Gentili et al., 2009; Stein, Goldin, Sareen, Zorrilla, & Brown, 2002; Straube, Mentzel & Miltner, 2005), faster attention engagement (Bantin, Stevens, Gerlach, & Hermann, 2015), and enhanced attention-related electroencephalography (EEG) components (e.g., P1 or N2pc) were found when individuals with SAD viewed threatening faces (Harrewijn, Schmidt, Westenberg, Tang, & Mjw, 2017; Meynadsey et al., 2020). These findings of attentional bias or hypervigilance in SAD can be interpreted by the vigilance–avoidance hypothesis, which proposes that individuals with social anxiety have initial hypervigilance and subsequent defensive avoidance responses to threat related images (Bögels & Mansell, 2004). Anxious participants would show faster orientation toward threat information at the initial stage but direct their attention away from threat information at a later stage.

Individuals with social anxiety show particular biases toward low-spatial-frequency (LSF) information when processing faces (Langner, Becker, & Rinck, 2009; Langner, Becker, & Rinck, 2012). For example, Langner, Becker and Rinck (2009) found that individuals with social anxiety used more LSF information than high-spatial-frequency (HSF) information when discriminating among emotional facial expressions. They also found that socially anxious individuals had better performance within LSFs in an implicit learning task (Langner, Becker & Rinck, 2012). Consistently, another study found that socially anxious individuals took a shorter time to discriminate among emotional faces when they were presented in LSFs (Langner, Becker, Rinck and Knippenberg, 2015). The preference for LSFs information among individuals with SAD may be caused by attentional bias accompanied by enhanced activation of the amygdala; studies have found that the amygdala has broad connectivity with the cortex and some subcortical structures, and during processing of significant information, the amygdala enhances sensory processing through both direct (amygdala–visual cortex) and indirect (amygdala–prefrontal cortex–visual cortex) paths (Pessoa and Adolphs, 2010). The LSF information of an image might be important for early warning of danger since it can be perceived from a long distance in a short time (De Cesarei & Codispoti, 2012).

Although LSF information in threat faces has been demonstrated to be important for socially anxious individuals (Langner, Becker, Rinck, & Knippenberg, 2015), the temporal dynamics of attentional bias toward threat faces within LSFs among individuals with social anxiety remain unclear. Event-related potential (ERP) measures can help elucidate the cognitive processes in the temporal processing stream. The P1 component (Thorpe, 2009; Thorpe, Fize, & Marlot, 1996) peaks around 100 ms, which is regarded as an index for early visual perception. Previous studies have found enhanced P1 for negative faces compared to neutral faces in LSFs but not HSFs (Pourtois et al., 2005; Vlamings et al., 2009; De Cesarei & Codispoti, 2011). P2 component occurs between 190 and 290 ms over occipital sites (Van Voorhis & Hillyard, 1977; Hillyard & Mangun, 1986; Schupp, Junghoefer, Weike, & Hamm, 2003; Schupp et al., 2004), reflecting attentional resources allocation. For example, increased P2 amplitude were found in response to negative versus positive-arousing pictures (Dennis and Chen, 2007; Eldar, Yankelevitch, Lamy, & Bar-Haim, 2010). However, previous studies only focused on healthy participants, it is unclear how socially anxious individuals would process LSF in threat faces in temporal stages.

In addition, most previous studies adopted one kind of threatening face (i.e., faces of anger, disgust, or fear) (Langner, Becker, & Rinck, 2009; Langner, Becker, & Rinck, 2012; Langner, Becker, Rinck, & Knippenberg, 2015). For example, Wieser, Hambach, and Weymar (2018) used angry faces as threat faces and found that individuals with high social anxiety showed attentional bias for both angry and happy faces; they claimed that individuals with high social anxiety may have attentional bias to general emotional faces rather than only threat faces. However, some other studies found that, when detecting emotional faces among neutral faces, socially anxious individuals showed an attentional bias toward angry faces but not happy faces (Eastwood and Smilek, 2005; Gilboa-Schechtman et al., 1999). One possibility for the inconsistencies in the previous findings is that different types of threat faces might have different effects. Although disgust, anger, and fear are all associated with threat, they have unique features that signify special forms of danger in our life. For example, differences in neural responses to different types of emotions (e.g., fear, disgust, and anger) have been found in healthy individuals (You & Li, 2016; Zhang, Liu, Wang, Ai, & Luo, 2016). Krusemark and Li (2013) found that fear and disgust scenes evoked amplified and reduced P1 responses compared to neutral scenes, while fear and disgust images evoked comparable N170 responses in later perceptual processing. Zhang, Liu, Wang, Ai, and Luo (2016) found a similar result that disgust faces exerted different attentional modulation compared to fear and anger faces. Disgust first diverts rather than capturing attention. It is still an open question whether SAD individuals have different neural responses to different types of threat emotions.

To address the above issues, faces of anger, disgust, and fear were presented in high and low spatial frequencies, we compared the neural correlates of sensory and attention processing in high social anxiety and low social anxiety individuals. The physical properties of the images were carefully balanced to exclude the possible impact of irrelevant variables on early visual ERPs. The luminance, contrast, size, and wavelet energy were equaled across SF and emotion conditions after spatial frequency filtering. The valence and arousal were balanced across the three emotions (anger, disgust, and fear). A visual search task was used to investigate the attentional effects of emotions and spatial frequencies. ERP measures focusing on the early P1 (Vuilleumier & Pourtois, 2007) and P250 (Krusemark & Li, 2011) components could provide information on the two stages of visual processing. The P250 component is a positive component occurring around 250 ms over occipital sites, which has the same topographical distribution and can be modulated by same manipulations as the P2 component (Schupp, Junghoefer, Weike, & Hamm, 2003; Schupp et al., 2004). The P250 has a slightly different timing compared to the P2 component because of search array in the task. We expected a P250 component because similar procedure was used as the previous study (Krusemark & Li, 2011).

According to the vigilance–avoidance hypothesis, we expected that socially anxious individuals would show enhanced early components and suppressed later components for LSF threatening faces compared to healthy controls.

2 Method

2.1 Participants

Fifty-one right-handed college students were recruited from 255 campus students using the Social Phobia Scale (SPS) and the Social Interaction Anxiety Scale (Mattick & Clarke, 1998). A power analysis suggested that approximately 48 participants were needed for a within-subjects design to achieve a power of 80% for a small effect size (d = .2). G*Power 3.1 was used to calculate the minimum sample size needed (Faul, Erdfelder, Lang, & Buchner, 2007). All participants had no head injury, psychological/neurological disorders, or current use of psychotropic medication. Three participants were excluded from EEG analysis due to excessive eye and muscle movements. Thus, the final sample consisted of 48 participants (HSA: n = 24, M = 21.21 years, SD = 1.89; LSA: n = 24, M = 22.67 years, SD = 3.29; eight males). All participants signed informed consent forms approved by the Capital Normal University Institutional Review Board before the study.

2.2 Anxiety screening tools

Participants were selected through two self-report measures before the experiment: The Social Phobia Scale (SPS) and the Social Interaction Anxiety Scale (SIAS), which were designed to assess anxiety related to social situations (Mattick & Clarke, 1998). These scales have been successfully applied to identify individuals with high social anxiety (Amir, Freshman, & Foa, 2002; Reutter, Hewig, Wieser, & Osinsky, 2017). Both measures were rated using a five-point scale ranging from 1 (very little) to 5 (very much) to assess the general patterns concerning each statement. The total score of these two measures was used as the index of social anxiety. According to previous study (Ye, Qian, Liu, & Chen, 2007), the cut-off point for the high social anxiety (HSA) group and low social anxiety (LSA) group was 67.93 and 117.53 ($M \pm SD$), respectively. The individual effects of the anxiety measure can be found in Table 1.

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2.3 Stimuli

One hundred and sixty faces were selected from the Chinese Affective Picture System (CAPS; Gong, Huang, Wang & Luo, 2011) to convey fear (20 male and 20 female), disgust (20 male and 20 female), anger (20 male and 20 female), or neutral (20 male and 20 female) content. A large sample of Chinese participants had made valence and arousal ratings for these pictures on a nine-point scale in a previous survey. A univariate ANOVA showed no significant differences in the valence scores of the three types of threat [$F(3,156) = 80.22$, $p < .001$, $\eta^2_p = .61$; mean ± standard error: anger = 2.87 ± .50, disgust = 2.94 ± .55, fear = 2.73 ± .44, neutral = 4.31 ± .59; anger vs. disgust: $p = .54$, anger vs. fear: $p = .23$, disgust vs. fear: $p = .07$]. However, the valence ratings of the three types of threat faces differed significantly from those of the neutral faces (ps < .001). A univariate ANOVA showed no significant differences in the arousal scores of the three types of threat faces [$F(3,156) = 59.61$, $p < .001$,

η^2_p = .53; mean ± standard error: anger = 5.92 ± 1.40, disgust = 6.37 ± .94, fear = 6.31 ± 1.22, neutral = 3.61 ± .51; anger vs. disgust: p = .06, anger vs. fear: p = .11, disgust vs. fear: p = .81]. However, the valence ratings of the three types of threat faces differed significantly from those of the neutral faces (ps < .001).

All faces were normalized to equal luminance and contrast and were transformed to equal-size grayscale photographs. A second-order 2D isotropic Butterworth low-pass filter of with a cut-off frequency of 15 cycles/image and a second-order 2D isotropic Butterworth high-pass filter with a cut-off frequency of 25 cycles/image were used to generate LSF and HSF images, respectively (Vuilleumier, Armony, Driver & Dolan, 2003; Alorda et al., 2007).

The SHINE toolbox (Willenbockel et al., 2010) was used to ensure the eight categories of images (H/LSF × anger/disgust/fear/neutral) were equated on luminance [116 (.2) on a 0-255 scale] and contrast [40 (.4)]. The spatial frequency was also matched across the four emotion conditions for each spatial frequency (SF) band using the SHINE toolbox.

2.4 Main experiment

Participants were seated 80 cm from a 15-inch cathode ray tube (CRT) monitor in a dimly lit room. A visual search task used in a previous study (Krusemark and Li, 2011; Figure 1B) was performed. The experiment consisted of 10 blocks with eight conditions [emotion (anger, disgust, fear, neutral) × spatial frequency (LSF, HSF)], each containing 120 trials. All images were randomly presented. As shown in Figure 1, each trial started with a white fixation at the center of a black background, followed by an image ($8.58^{\circ} \times 10^{\circ}$ visual angle) centrally displayed for 150 ms. Then, a search array (including 20 kinds of search arrays) was superimposed on the image for 1,000 ms. The search array consisted of one horizontal bar (target) and seven vertical bars (distracters) displayed in green. The participants were required to indicate the quadrant of the target by pressing a button on the computer keyboard. The locations of the targets were equally distributed among the four quadrants. Stimulus presentation was delivered using Presentation software (Neurobehavioral Systems, San Francisco, CA).

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2.5 EEG recording and analysis

EEG data were recorded throughout the experiment using the Neuroscan system according to the extended international 10-20 system (Picton et al., 2000) using 62 Ag/AgCl electrodes positioned in an elastic nylon cap. EEG recordings were referenced to the left mastoid, and signals were re-referenced to the average of the left and right mastoids.

The vertical and horizontal electrooculograms (VEOG and HEOG) were recorded using four additional electrodes (two electrodes were placed 1 cm to the left and right of the outer canthi to monitor the horizontal electrooculogram; another two electrodes were placed above and below the left eye to monitor vertical electrooculogram). Signals from all channels (sampling rate 500 Hz) were digital bandpass filtered from .05 to 100 Hz (online) or from .05 to 40 Hz (offline) using the Neuroscan Scan 4.5 software. During recording, the impedance was maintained below 5 kΩ. Both P1 and P250 components were time-locked around face picture onset (from -200 ms to 1,000 ms). Trials with voltages exceeding ±75 μV were excluded from analyses after EOG blink artifact correction (on average, no more than 15% of the trials in each condition) was conducted using a linear regression estimate (Semlitsch, Anderer, Schuster, & Presslich, 1986). We applied an independent t-test on the rejection rates for HSA and LSA groups. No significant difference was found between the HSA (*M* = .044, *SD* = .036) and LSA groups (*M* = .077, *SD* = .094), *t* (46) = -1.598, *p* = .121.

The mean amplitudes of the occipital P1 and occipital P250 components (calculated at the electrode sites of O1, OZ, O2, PO3, POZ, and PO4) were analyzed. The time windows of P1 and P250 were centered on the peak of the group amplitude (94-130 ms and 218-246 ms, respectively), and the intervals were decided based on a previous study (Krusemark and Li, 2011) and visual inspection of the waveforms in the current study.

2.6 Statistical analysis

Three-way repeated measures ANOVAs with within-subject factors of emotion (anger, disgust, fear, and neutral) and spatial frequency (HSF, LSF) and a between-subject factor of group (HSA, LSA) were performed on search reaction time (RT) and accuracy, as well as the P1 and P250 mean amplitudes.

3 Results

3.1 Behavior

The main effect of emotion on search speed was significant [F (3,138) = 4.593, p = .005, η^2_p = .091]. Planned comparisons indicated that RT was slower following anger [*M*(*SD*) = 604.9 ms (8.0)] than the other three types of emotion [disgust = 601.2 ms (8.0), anger vs. disgust: $p < .05$; fear = 601.5 (7.9), anger vs. fear: $p < .05$; neutral = 599.7 (7.7), anger vs. neutral: $p < .01$]. The emotion × spatial frequency interaction was significant [F(3,138) = 6.441, p = .001; η^2_p = .123], and simple effect analysis indicated that when the faces were presented at high spatial frequency, the RT following anger [*M*(*SD*) = 613.1 ms (8.2)] was longer than that following the other three types of emotion (shown in Figure 2) [disgust = 603.8 ms (8.0), anger vs. disgust: $p < .01$; fear = 604.8 (8.3), anger vs. fear: $p < .01$; neutral = 603.9 (7.8), anger vs. neutral: $p < .01$]. However, when the faces were presented at low spatial frequency, the RT did not differ significantly among different emotions ($p > .05$).

There was also a main effect of spatial frequency [$F(1,46) = 55.909$, $p < .001$; $\eta^2_p = .549$]; the RT following high-spatial-frequency faces [*M*(*SD*) = 606.4 ms (8.0)] was longer than that following low-spatial-frequency faces [*M*(*SD*) = 597.2 ms (7.8)]. A main effect of group was also found [$F(1,46) = 6.836$, $p = .012$; $\eta^2_p = .129$]; the RT of the HSA group [*M*(*SD*) = 581.3 ms (11.1)] was shorter than that of the LSA group [*M*(*SD*) = 622.4 ms (11.1)]. There was no main effect or interaction effect on search accuracy, and the accuracy rate in this experiment was 95.5 ± 3.42%.

----- INSERT FIGURE 2 ABOUT HERE -----

3.2 P1 component (94–130 ms)

The main effect of spatial frequency on the P1 amplitudes was significant [$F(1,46) = 10.681$, $p = .002$; $\eta^2_p = .188$]; when the faces were presented at low spatial frequency, the P1 amplitudes (3.02 ± .34 μV) were significantly larger than when the faces were presented at high spatial frequency (1.62 ± .52 μV) (shown in Figure 3). There was also a main effect of emotion [$F(3,138) = 4.399$, $p = .011$; $\eta^2_p = .087$]; the P1 amplitudes following the faces of neutral ($p = .009$) and disgust ($p = .033$) were significantly larger than those following the faces of fear [neutral (2.53 ± .41 μV) > disgust (2.37 ± .39 μV) > anger (2.35 ± .39 μV) > fear (2.04 ± .40 μV)].

----- INSERT FIGURE 3 ABOUT HERE -----

3.3 P250 component (218–246 ms)

The interaction effect of spatial frequency by group on the P250 amplitudes was significant [F (1,138) = 4.79, p = .034; η^2_p = .094]. Simple effect analysis indicated that the effect of spatial frequency significantly influenced the P250 amplitudes of the HSA group (p < .001), but not the LSA group (p > .05). For the HSA group, the P250 amplitudes following the high-spatial-frequency faces (8.17 ± .84 μV) were significantly larger than those following the low-spatial-frequency faces (6.26 ± .67 μV). However, for the LSA group, there was no significant difference in P250 amplitudes between different spatial frequency levels.

The interaction effect of emotion by group on the P250 amplitudes was significant [F (3,138) = 5.169, p = .003; η^2_p = .101]. For the HSA group, the P250 amplitudes following the faces of disgust were significantly larger than those following the faces of fear [disgust (7.51 ± .76 μV) > neutral (7.26 ± .74 μV) > anger (7.17 ± .72 μV) > fear (6.92 ± .75 μV); disgust vs. fear: p < .05]. For the LSA group, the P250 amplitudes following the faces of fear and disgust were significantly larger than those following the faces of neutral (shown in Figure 3B and Figure 4) [fear (8.47 ± .75 μV) > disgust (8.33 ± .76 μV) > anger (8.07 ± .72 μV) > neutral (7.66 ± .74 μV); disgust vs. neutral: p < .05; fear vs. neutral: p < .05]. To rule out the possible confound related to eye movements, we further analyzed the EOG data during the P250 window, none of the effects were significant (See Supplemental Information).

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4 Discussion

This study examined the temporal dynamics of perceptual and attentional responses to LSF information in individuals with social anxiety disorder and sought to examine differential processes of different types of threat faces between socially anxious individuals and healthy participants. Using spatial frequency-filtered face images and ERPs, we assessed the perceptual and attentional neural responses to different types of threat facial expressions in HSA and LSA individuals. In the early visual processing stage (reflected by P1), both HSA and LSA individuals showed perceptual facilitation for LSFs (vs. HSFs). In the later attentional processing stage (reflected by occipital P250), only HSA individuals showed different (suppressed) response patterns to LSF and HSF faces. Taken together, distinct responses between HSA and LSA individuals for LSF and HSF faces were found in attention but not in visual perception.

The behavior results of this study are consistent with previous research (Krusemark & Li, 2011). The longer RT for HSF faces indicated that HSF faces attracted more attention because they carry upper-level and detailed sensory information (Ullman et al., 2002). In addition, the convergent pronounced occipital P1 in response to LSF faces and more pronounced occipital P250 in response to HSF faces in this study were in line with the coarse-to-fine processing strategy, which suggests that in the early processing stage, only the coarse information of a visual item can be perceived (Sripati and Olson, 2009; Sugase, Yamane, Ueno, & Kawano, 1999). The current study showed that individuals with high social anxiety have perceptual bias for LSF faces regardless of the emotion.

In accordance with previous study (Krusemark & Li, 2011), the search performance and the P250 results are consistent: the early face perception modulated the allocation of attention (as reflected by P250 magnitude), resulting in different performance of visual search task. The results showed that search array following disgust faces had heightened attention (larger P250 magnitude) and better task performance (shorter response time). By contrast, angry faces suppressed visual attention (smaller P250 magnitude) and worse performance (longer response time). Using pictures of fearful and disgust natural objects, Krusemark and Li (2011) found that fearful images had augmented P250 magnitude and better task performance. Disgust images, however, had diminished P250 magnitude and slower response time. The results of current study had the same pattern as Krusemark and Li (2011), though our study used faces instead of natural objects. Disgust natural objects evoke ‘disease avoidance system’ and provokes rejection of sensory input (Rozin and Fallon, 1987), resulting in diminished P250 magnitude. However, disgust faces may draw extra attention of anxious individuals as they evoke negative self-beliefs (e.g., “others dislike me”), causing enhanced P250 magnitude. Note that the search array was balanced between different valence conditions, thus the P250 difference of different valence conditions is not likely indexing perceptual processing of the search array.

Moreover, we found the processing of LSF and HSF information in face pictures was modulated by anxiety. The P250 amplitudes following HSF faces were significantly larger than those following LSF faces only in the HSA group. These results support the vigilance-avoidance hypothesis, which posits that socially anxious individuals show an initial hypervigilance and later avoidance toward threatening information (Mogg, Bradley, Miles, & Dixon, 2004). This significant SF-by-group interaction effect on P250 potentials further accentuates the significance of LSF information for emotional face processing in socially anxious individuals.

We also found that anxiety influenced the processing of emotional facial expression, which was reflected by the significant emotion-by-group interaction effects on P250 amplitude. Unlike LSA individuals, HSA individuals could regard the face of disgust as more threatening than the face of fear. Moreover, the P1 amplitudes following the faces of disgust and neutral were significantly larger than those following the faces of fear. Many studies support that the disgust face is more important than other threatening faces among high anxious people. For example, a previous study found that a fearful face with direct gaze is not as intense as disgusted and angry faces because the observer is not the source of the threat (Hadjikhani, Hoge, Snyder, & de Gelder, 2008). Studies also found that socially anxious individuals rated disgust faces as more negative than the anger faces; whereas, non-anxious individuals did not rate the two emotions differently (Amir et al., 2010). Study also found that individuals with high trait anxiety tend to classify morphed face (blended angry and disgusted expressions) as disgusted expressions (Richards et al., 2002). HSA individuals may perceive disgust faces as more negative than other faces because they fear provoking others' disgusting more than other emotions (American Psychiatric Association [APA], 2000).

The emotion-by-group interaction effects on P250 amplitude found in our study can help clarify the inconsistent results of previous studies. Some studies concluded that individuals with high social anxiety had attentional bias for emotional faces in general instead of only threatening faces from the result that individuals with high social anxiety showed larger N2pc amplitudes (enhanced attention) to angry and happy faces (Wieser, Hambach, & Weymar, 2018). This inference should be made with caution since angry and happy faces may cause a similar reaction in individuals with high social anxiety in terms of negative bias, and angry faces show different processing patterns from disgusted and fearful faces. Future studies should pay attention to specific types of threat faces instead of regarding them as a group.

In sum, the results of this study shed a light on how the attention modulation of socially anxious individuals is affected by different types of threatening faces based on spatial frequency channels. The current study found that individuals with high social anxiety have an initial hypervigilance and later avoidance toward LSFs during visual search tasks. There was no difference between the HSA and LSA group in sensory perception because the subjects were not required to pay attention to the faces. The findings of different attention modulation patterns in response to neutral faces between the HSA and LSA group support the abnormal processing of emotional faces in social anxiety (Bögels & Mansell, 2004). Most importantly, the specific facet of the initial hypervigilance and later avoidance toward LSFs and the abnormal processing of emotional faces in social anxiety can be used to create more targeted attentional bias modification training.

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6 Open Practices Statements

The data and materials for all experiments are available at https://osf.io/j27vd/ and none of the experiments was preregistered.

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Table 1: The anxiety measure of HSA and LSA *M*(SD)

	HSA(*n*=24)	LSA(*n*=24)	*t*	*p*
Age (years)	21.21(1.89)	22.67(3.29)	-1.882	.066
Total score of SPS and SIAS	116.13(16.90)	56.33(7.48)	15.85	.000

Figure 1. Visual search paradigm. Each trial started with a white fixation at the center of a black background, followed by a face image (8.58° × 10° visual angle) centrally displayed for 150 ms. Then, a search array was superimposed on the image for 1,000 ms.

Figure 2. Visual search results. The response time following HSF faces was longer than that following LSF faces. When the faces were presented at high spatial frequency, the RT following angry faces was longer than that following the other three types of faces. $*p < .01$.

Figure 3. Neurophysiological responses. (A) P1 and P250 at Oz indicate enhanced P1 and reduced P250 for LSF faces. (B) Mean amplitude of P250 between 218-246ms in different conditions. In HSA group, the mean amplitude of P250 following faces of disgust were larger than those following the faces of fear. In LSA group, the mean amplitude of P250 following faces of fear and disgust were larger than those following neutral faces. Error bars indicate the standard error.

Figure 4. (A) In the HSA group, the P250 amplitudes following faces of disgust were larger than those following the faces of fear. (B) In the LSA group, the P250 amplitudes following faces of fear and disgust were larger than those following neutral faces. (C) Scalp topographies of the difference between two conditions (A-N, anger vs. neutral; D-N, disgust vs. neutral; F-N, fear vs. neutral) during the 200-300 ms interval.

Two-way mixed measures ANOVAs with within-subject factor of spatial frequency (HSF, LSF) and a between-subject factor of group (HSA, LSA) were performed on HEOG and VEOG mean amplitudes. For the HEOG there was no main effect of spatial frequency [F (1,46) = 1.143, p = .707; η^2_p = .003] or group [F (1,46) = .064, p = .801; η^2_p = .001], neither was there the interaction [F (1,46) = 1.001, p = .322; η^2_p = .021, HSA-HSF (M = .46, SD = 3.04), HSA-LSF (M = .84, SD = 3.99), LSA-HSF (M = .90, SD = 2.58), LSA-LSF (M = .07, SD = 2.48)]. For the VEOG, there was also no main effect of spatial frequency [F (1,46) = .017, p = .90; η^2_p = .00] or group [F (1,46) = .47, p = .50; η^2_p = .01], neither was there the interaction [F (1,46) = .17, p = .90; η^2_p = .00, HSA-HSF (M = -.44, SD = 8.75), HSA-LSF (M = -.44, SD = 7.17), LSA-HSF (M = .42, SD = 11.20), LSA-LSF (M = .90, SD = 6.47)].

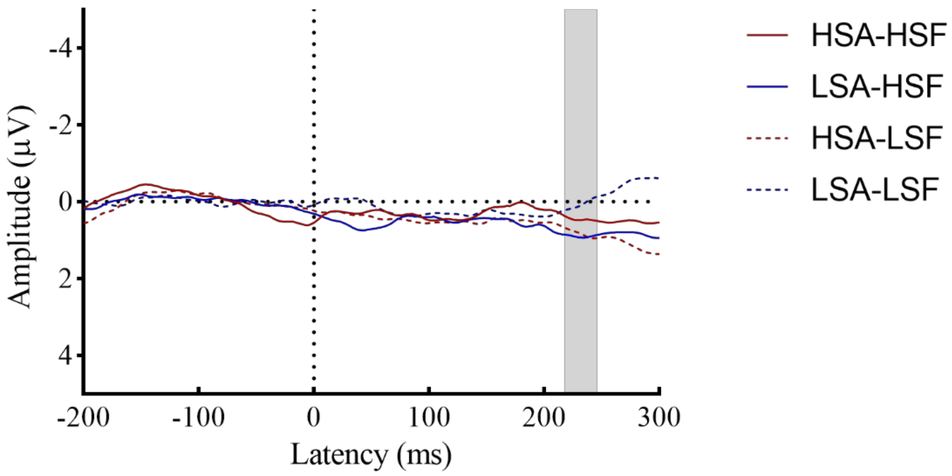

Figure 1: Grand average HEOG amplitude for HSA and LSA group of different spatial frequency. The grey shade part reflects the P250 window.

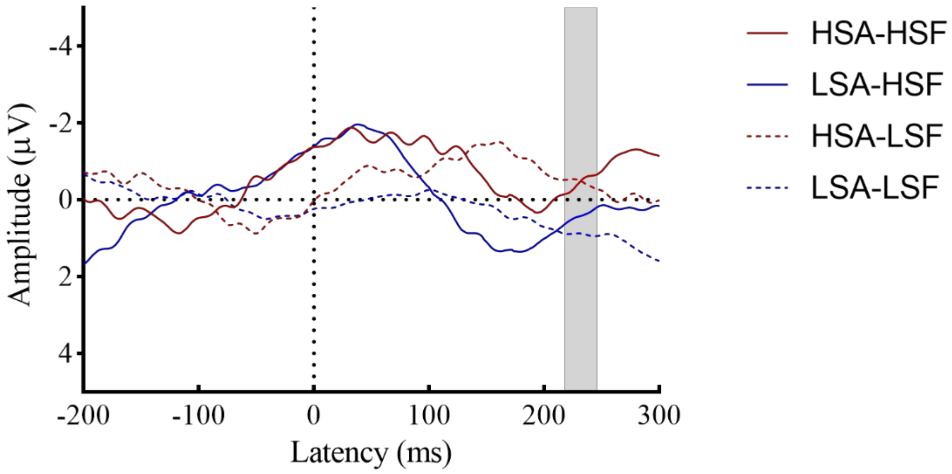

Figure 2: Grand average VEOG amplitude for HSA and LSA group of different spatial frequency. The grey shade part reflects the P250 window.