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Sustained visual attention for competing emotional stimuli in social anxiety: An eye tracking study

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ABSTRACT

Background and objectives: Numerous studies have supported attentional biases toward social threats in socially anxious individuals. The aim of the present study was to investigate the time-course of sustained attention for multiple emotional stimuli using a free-viewing paradigm in social anxiety.
Methods: Thirty-two socially anxious (SA) and 30 non-anxious (NA) participants completed the free-viewing task. Participants were presented with a face array composed of angry, sad, happy and neutral faces for 10 s in each trial. Eye movements were recorded throughout the trial to assess the time-course of attentional processing.
Results: Although SA participants did not exhibit initial orienting bias, they had higher fixation probability for angry faces during the 250–1000 ms time intervals, relative to NA participants. SA participants also maintained their attention longer than NA participants did when angry faces were initially fixated upon. Moreover, NA participants showed higher fixation probability for happy faces during the 6–8 s after stimulus onset. We failed to observe attentional avoidance of threat in SA participants.
Limitations: First, this study used a non-clinical sample. Second, the stimuli used in this study were static.
Conclusions: The present findings suggest that, relative to non-anxious individuals, socially anxious individuals are characterized by enhanced engagement with social threat at an early stage of processing and difficulty in disengaging from social threat once their initial attention is located on it. Conversely, non-anxious individuals are characterized by enhanced engagement with positive stimuli at a later stage of processing.

1. Introduction

Cognitive theories have assumed that anxious individuals are hypersensitive to information that signifies a threat or danger (Beck & Emery, 1985; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997). In the context of social anxiety, numerous studies have supported the hypothesis that socially anxious individuals show attentional biases toward socially threatening stimuli (e.g., threatening faces) (Bantin, Stevens, Gerlach, & Hermann, 2016; Staugaard, 2010). However, attentional biases might comprise different components (Cisler & Koster, 2010). A vigilance-avoidance hypothesis states that socially anxious individuals automatically orient their initial attention toward threats but subsequently direct their attention away from threats (Mogg, Bradley, De Bono, & Painter, 1997; Williams et al., 1997). The delayed disengagement hypothesis claims that socially anxious individuals are characterized by difficulty in disengaging attention from social threats (Amir, Elias, Klumpp, & Przeworski, 2003).

As suggested by Weierich, Treat, and Hollingworth (2008), the two hypotheses might not be incompatible when the duration of stimulus presentation extends over multiple seconds. Attentional vigilance toward threat might occur at an early stage of presentation and be followed by delayed disengagement from threat (Cisler & Koster, 2010; Moriya & Tanno, 2011; Weierich et al., 2008). The phenomenon of attentional avoidance, which is assumed to be a controlled strategy for emotion regulation, might be observed at a comparatively late stage of information processing (i.e., after a presentation time of 1250 ms or longer) (Cisler & Koster, 2010;

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Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006; Weierich et al., 2008).

In recent years, considerable concern has arisen over the time-course of attentional bias to socially threatening information in social anxiety (Staugaard, 2010). The most commonly used paradigm to investigate selective attention for social information in social anxiety is the dot-probe task using facial expressions as stimuli (Bantin et al., 2016). However, the dot-probe task has been criticized because it relies on a key-press reaction time to index allocation of attention. Reaction time might be confounded by other cognitive processes (Staugaard, 2010) and variable motor speed (Mogg, Millar, & Bradley, 2000). Moreover, the dot-probe task does not indicate the time-course of attentional processing over the stimulus duration. Several authors have suggested that an eye tracking paradigm appears to be a more promising tool for investigating the time-course of attentional processing for emotional stimuli because it provides a relatively continuous measurement of attentional processing under a more natural condition (Eizenman et al., 2003; Kellough, Beevers, Ellis, & Wells, 2008).

Eye tracking has been widely used in research on attentional biases of patients with social anxiety disorder or individuals with high social anxiety (Gamble & Rapee, 2010; Garner, Mogg, & Bradley, 2006a; Schofield, Inhoff, & Coles, 2013; Seefeldt, Kramer, Tuschen-Caffier, & Heinrichs, 2014; Stevens, Rist, & Gerlach, 2011). Researchers have commonly used a free-viewing paradigm to examine participants' sustained attention toward emotional stimuli. In such studies, participants are asked to freely view two or four pictures displayed for several seconds (i.e., 5 s, 10 s or longer) in each trial. Eye movements during each trial were continuously recorded to investigate the time-course of attentional processing. In free-viewing studies, attentional vigilance toward social threats can be measured with the probability of initial fixation on threatening faces and the probability of fixation on threatening faces at an early stage (e.g., the first 500 ms). The former indexes participants' initial orienting toward threats and the latter indexes facilitated engagement toward threats at an early stage (Armstrong & Olatunji, 2012; Nummenmaa, Hyona, & Calvo, 2006; Richards, Benson, Donnelly, & Hadwin, 2014). Furthermore, the duration of initial fixation on threatening stimuli is commonly used to assess attentional maintenance and to examine whether an anxious individual has difficulty in disengaging from threats (Garner et al., 2006a). Attentional avoidance refers to a tendency to avoid allocating attention to threatening stimuli and is indicated by a lower probability of fixating on threatening stimuli at a later stage of attentional processing.

One meta-analysis of eye movement studies in affective disorders has supported the hypothesis that anxious individuals demonstrate increased vigilance toward threats and have difficulty in disengaging attention from threats (Armstrong & Olatunji, 2012). However, this analysis did not specially focus on social anxiety but included studies of a variety of different types of anxiety. With regard to social anxiety, most studies have used a free-viewing task with face pairs (e.g., angry-neutral pair) as stimuli. In addition to conducting an event-related analysis of the critical first eye movement event (i.e., the first fixation), some studies have also conducted epoch-related analysis by dividing the stimulus duration into several temporal segments (i.e., time bins) to examine the time-course of attentional processing. Some studies have shown attentional vigilance toward threatening faces in social phobia (Gamble & Rapee, 2010; Seefeldt et al., 2014; Stevens et al., 2011), while other studies have failed to support these findings. Other studies have found that socially anxious individuals showed attentional avoidance of both positive and negative faces (Byrow, Chen, & Peters, 2016; Chen, Clarke, MacLeod, & Guastella, 2012). Schofield et al. (2013) reported that over time, participants with social phobia paid less attention to emotional faces, especially to happy faces. Another study found that socially anxious individuals demonstrated difficulty in disengaging from threatening faces (Buckner, Maner, & Schmidt, 2010b).

Although facial expressions are important signs of evaluation by others within social situations (Mansell, Clark, Ehlers, & Chen, 1999), face pairs may be too simple to resemble a real social situation and to induce anxious individuals' feelings of being threatened. Some researchers have suggested that research on threat-related attentional biases should use more complex stimuli arrays with various competing emotional stimuli (e.g., threatening, non-threatening and positive) presented simultaneously (Richards et al., 2014). Lazarov, Abend, and Bar-Haim (2016) utilized a free-viewing paradigm that presented a 4×4 matrix comprising eight disgusted and eight neutral facial expressions for 6 s. They found that socially anxious participants spent more time fixating on threatening faces. Although Lazarov et al. used a matrix of 16 faces in their study, they included only two categories of facial expressions (i.e., disgusted and neutral) in a matrix. Buckner, Dewall, Schmidt, and Maner (2010a) used a 2×2 matrix including angry, sad, happy and neutral facial expressions for 30 s. They found that the highly socially anxious participants allocated more attention to negative faces in the absence of social-exclusion threat. Unfortunately, neither of these studies addressed the time-course of attentional processing during stimuli presentation.

The present study aims to investigate the time-course of sustained attention for multiple emotional stimuli in individuals with social anxiety. We used a free-viewing task that presented a matrix of four faces including angry, sad, happy and neutral faces for a relatively long stimulus duration (i.e., 10 s). This task was designed to simulate an ambiguous social situation containing positive, negative, and neutral information. Angry faces have been frequently used to evaluate threat-related attentional bias in previous studies of social anxiety (Staugaard, 2010). Although some research suggests that disgusted faces may be more relevant for social anxiety-related fears, we chose angry faces to represent threatening stimuli because the angry expression has been assumed to be the most salient sign of criticism and hostility in social situations (Ekman, 1973; Staugaard, 2010). The location of initial fixation and initial gaze duration were used to index the initial orienting and maintenance of attention, respectively. To evaluate changes in attentional processing in detail in the early phase, the first 2 s of the stimulus duration were divided into eight time bins of 250 ms, because studies have suggested that we generate 3–4 fixations per second (Hoffman, 1998; Rayner, 1998). To explore sustained attention for emotional faces in social anxiety, we also divided the 10-s stimuli duration into five 2-s time bins. Socially anxious participants were predicted to be more likely to fixate on angry faces initially and to fixate on angry faces at an early stage (i.e., vigilance). They were also expected to exhibit a longer initial gaze duration when angry faces were initially fixated upon (i.e., difficulty in disengagement). Moreover, we hypothesized that socially anxious participants would have a lower probability of fixating on angry faces at a relative late stage (>1250 ms) and that they would continuously inhibit to fixate on angry faces during sustained exposure to emotional faces (i.e., avoidance).

2. Method

2.1. Participants

The participants in this study were recruited from a large pool of potential participants at a university in Taiwan. Socially anxious (SA) and non-anxious (NA) groups of participants were selected based on their scores on the Brief Fear of Negative Evaluation Scale (BFNE; Leary, 1983). Participants who scored in the highest quartile (BFNE≧45) and scored below the mean (BFNE≦40) were defined as the SA and NA groups, respectively. Thirty-two SA and thirty NA participants volunteered to participate in this study. All participants were Asian students.

The SA participants reported significantly higher level of social anxiety (BFNE score), t (60) = 17.41, $p < 0.001$, $d = 4.41$, trait anxiety, t (60) = 8.38, $p < 0.001$, $d = 2.14$, and depressive of symptoms, t (60) = 4.07, $p < 0.001$, $d = 1.04$, compared with the NA participants. The groups did not differ in terms of age, t (60) = −1.63, $p = 0.11$, $d = 0.00$, or gender ratio, χ^2 (1, $N = 62$) = 0.02, $p = 0.88$, $w = 0.02$. The participants' characteristics are described in Table 1.

2.2. Measures

The BFNE is a 12-item scale measuring fear of negative evaluation from others, which is the hallmark of individuals with high social anxiety. The State Trait Anxiety Inventory-Trait (STAI-T; Speilberger, Gorsuch, Lushene, Vagg, & Jocobs, 1983) is a 20-item scale assessing an individuals' predisposition to experience anxiety. The Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996) is a 21-item scale measuring the severity of depressive symptoms. The Chinese version of each scale has been found to possess acceptable internal consistency (BFNE, $\alpha = 0.87$; STAI-T, $\alpha = 0.86$; BDI-II, $\alpha = 0.86$) and construct validity (Chang, 2005; Chen, 2000; Chung & Long, 1984; Liang, Hsu, Hung, Wang, & Lin, 2011). All of these scales have good internal consistencies (BFNE, $\alpha = 0.92$; STAI-T, $\alpha = 0.93$; BDI-II, $\alpha = 0.87$) in the present study.

2.3. Materials and apparatus

The stimuli of this study consisted of sixteen slides containing four facial expressions from the same person (i.e., angry, sad, happy and neutral expressions) presented in the 2 × 2 matrices. The faces used in this study were selected from the Taiwan corpora of Chinese emotions and relevant psychophysiological data as follows: A college student database of facial expressions for basic emotions (Shyi, Huang, & Yeh, 2013) that contains a standardized set of emotional expressions. All of the photographs in this database have been systematically rated for emotional intensity for each emotional category. Sixteen individuals (8 males and 8 females) displaying angry, sad, happy and neutral expressions were selected for this study.

A total of 64 photographs were rated by 50 undergraduates (30 males and 20 females) on 9 point scales for valence (unpleasant = 1 to pleasant = 9) and arousal (calm = 1 to excitement = 9) using the Self-Assessment Manikin (SAM), a pictorial technique developed for measuring a person's affective reaction to visual stimuli (Lang, Bradley, & Cuthbert, 1999). Significant differences among the four face types were found on ratings of valence and arousal, F (3, 60) = 236.42, $p < 0.001$ and F(3, 60) = 70.88, $p < 0.001$, respectively. The post hoc Scheffe tests showed that the valence ratings for happy ($M = 6.15$, $SD = 0.34$) faces were higher than the other three face types (neutral, $M = 4.63$, $SD = 0.30$; sad, $M = 3.40$, $SD = 0.40$; angry, $M = 3.17$, $SD = 0.37$). The valence ratings for angry and sad faces were significantly lower than those for neutral faces, whereas the valence ratings for angry and sad faces were not different from each other. For arousal ratings, neutral faces ($M = 3.20$, $SD = 0.19$) had lower arousal ratings than the other three face types (angry, $M = 4.61$, $SD = 0.30$; happy, $M = 4.46$, $SD = 0.31$; sad, $M = 4.40$, $SD = 0.40$). There were no significant differences among the angry, happy and sad faces.

Slides were presented on a 17-in monitor with a resolution of 1024 × 768 pixels. Each of the four facial images presented on each slide was 320 × 240 pixels (10.3° × 7.7° of the visual angle). The center of each image was located at 14.2° of the visual angle distance from the fixation cross (see Fig. 1). Each type of facial expression appeared equally often on each location of the slide. Eye movements were continuously recorded by the iView X Hi-speed eye-tracking system (SensoMotoric Instruments, Germany) during the stimulus presentation time for each trial.

Table 1
Mean and standard deviation for group characteristics.

	SA (n = 32)		NA (n = 30)	
	M	*SD*	*M*	*SD*
Sex (% female)	75%		73.3%	
Age	18.66	1.47	19.27	1.48
BFNE	51.56	4.60	28.10	5.96
STAI-T	54.72	9.09	37.60	6.74
BDI-II	12.34	6.85	6.30	4.53

Note: SA = socially anxious group; NA = non-anxious group; BFNE = Brief Fear of Negative Evaluation Scale; STAI-T = State Trait Anxiety Inventory-Trait; BDI-II = Beck Depression Inventory-II.

2.4. Procedure

After signing an informed consent form, participants read written instructions about the purpose and procedure of the experiment. To provide a cover story, we told participants that the purpose of the experiment was to measure pupil diameter in response to emotional stimuli. This cover story did not include a mention of recording of eye movements in order to minimize demand effects (Kellough et al., 2008).

The participants were seated in front of the monitor, and a chin rest was used to fixed their head position. The distance between the participant's eye and the monitor was approximately 60 cm. After a 9-point calibration and validation were completed, participants were instructed to view the slides on the monitor naturally, as if they were watching television. Each trial began with a fixation cross on the center of the screen and the participant was required to look at the fixation cross until the slide displayed. Once the participant fixated on the fixation cross, the experimenter pressed a key to display the slide. Each slide disappeared after 10 s and was displaced by a fixation cross of the next trial. The 16 slides were presented in random order for each participant. The procedures were approved by the Psychology Department's Human Subjects Review Committee of a university in Taiwan.

2.5. Data analyses

Gaze positions were sampled every 2 ms (i.e., 500 samples per second). Fixations were defined as at least 100 ms of stable fixation within 1 visual angle. For each trial, four regions of interest (ROIs) were identified, corresponding to the four face regions. To index the initial orienting and maintenance of initial attention, we analyzed the initially viewed face for each trial by computing the probability of the initial fixation and the duration of gaze on the initially fixated face. The probability of the initial fixation was computed by counting the number of trials in which the first fixation was located in a particular face valence, divided by the total number of trials. The duration of gaze on the initially fixated face was the sum of the duration of all fixations of the first entry to the initially fixated face before a shift in gaze away from it. The probability of the initial fixation and the duration of gaze on the initially fixated face were analyzed by mixed analyses of variance (ANOVAs) with the group

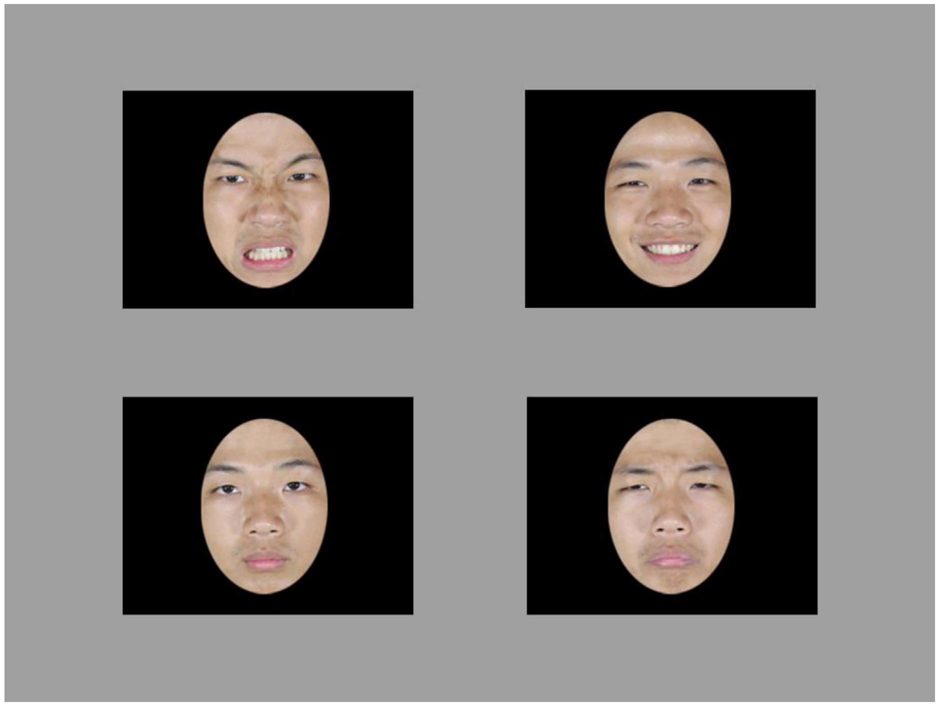

Fig. 1. An example of a study slide (top left: angry face; top right: happy face; bottom left: neutral face; bottom right: sad face).

as a between-subjects factor and face valence as a within-subjects factor.

To investigate the time-course of attentional processing for different emotional faces, we analyzed the eye movement data by dividing the first 2 s of stimulus durations into eight time bins of 250 ms and the 10 s of stimulus durations into six time bins of 2 s. The fixation probability for each of these time bins was computed by counting the number of gaze samples landed on each face valence, divided by the total gaze samples for each time bin. We performed the mixed ANOVAs with the group as a between-subjects factor and face valence and time bins as within-subjects factors on fixation probability over time.

3. Results

3.1. Probability of the initial fixation

A 2 (group: socially anxious, non-anxious) × 4 (face valence: angry, sad, happy, neutral) mixed ANOVA[1] was conducted on the probability of the initial fixation. The results revealed a non-significant main effects for face valence, F (3, 180) = 1.85, p = 0.14, η_p^2 = 0.03, and a non-significant group × face valence interaction, F (3,180) = 0.55, p = 0.65, $\eta_p^2 < 0.01$ (See Table 2).

3.2. Duration of gaze on the initially fixated face

A 2 (group: socially anxious, non-anxious) × 4 (face valence: angry, sad, happy, neutral) mixed ANOVA[2] was conducted on the duration of gaze on the initially fixated face. Analyses showed a significant main effect of face valence, F (3, 180) = 8.06, p = 0.001, η_p^2 = 0.11, and a significant interaction of group and face valence, F (3, 180) = 6.12, p = 0.001, η_p^2 = 0.09. Planned comparisons indicated that the SA participants looked significantly longer at angry faces than NA participants, t (60) = 2.86, p = 0.006, d = 0.73. There were no group differences for the other three types of faces (ps > 0.05). In the SA group, the participants looked significantly longer at angry faces than at sad, happy and neutral faces (ps < 0.001); there were no significant differences between the other three face types (ps > 0.05). In the NA group, no significant differences were found between the different face types (ps > 0.05) (See Table 2).

Table 2
Mean and standard deviation for proportion of initial fixations on each face type and gaze duration on initial fixated face.

	Location of initial fixation (%)				Gaze duration on initial fixated face			
	SA (n = 32)		NA (n = 30)		SA (n = 32)		NA (n = 30)	
	M	SD	M	SD	M	SD	M	SD
Angry	27.54	7.25	25.83	8.16	1094.12	476.78	775.01	394.57
Sad	24.81	9.19	26.25	6.64	779.60	347.61	788.53	376.61
Happy	24.02	7.95	25.42	7.51	828.69	340.01	755.63	344.97
Neutral	23.63	6.29	22.50	7.63	811.58	293.77	699.74	351.82

Note: SA = socially anxious group; NA = non-anxious group.

[1] We also conducted two-way ANCOVAs using the BDI-II scores as a covariate variable. The results revealed a non-significant main effects for face valence, F (3, 177) = 0.41, p = 0.74, ηp^2 = 0.01, and a non-significant group × face valence interaction, F (3,177) = 0.59, p = 0.62, ηp^2 = 0.01.

[2] We also conducted two-way ANCOVAs using the BDI-II scores as a covariate variable. There was a significant main effect of face valence, F (3, 177) = 2.97, p = 0.03, ηp^2 = 0.05, and a significant interaction of group and face valence, F (3, 177) = 5.66, p = 0.001, ηp^2 = 0.09. Planned comparisons indicated that the SA participants looked significantly longer at angry faces than NA participants, F (1, 59) = 4.91, p = 0.03, ηp^2 = 0.08. There were no group differences for the other three types of faces (ps > 0.05). In the SA group, the participants looked significantly longer at angry faces than at sad, happy and neutral faces, ps < 0.001; In the NA group, no significant differences were found between the different face types, ps > 0.05.

3.3. Fixation probability during the first 2 s

A 2 (group: socially anxious, non-anxious) × 4 (face valence: angry, sad, happy, neutral) × 8 (time bins: 0–250 ms, 250–500 ms, 500–750 ms, 750–1000 ms, 1000–1250 ms, 1250–1500 ms, 1500–1750 ms, 1750–2000 ms) mixed ANOVA[3] was conducted on fixation probability during the first 2 s. Analyses revealed a near-significant three-way interaction, F (21, 1260) = 1.45, p = 0.08, $\eta_p^2 = 0.02$. To explore this interaction, separate two-way ANOVAs were computed for each face valence. For angry faces, the group × time bin interaction was significant, F (7, 420) = 2.85, $p = 0.007$, $\eta_p^2 = 0.05$. Planned comparisons revealed that no significant difference between the two groups was found during the 0–250 ms time bin, t (60) = 0.58, p = 0.56, d = 0.14. However, the SA participants showed significantly higher fixation probability for angry faces than the NA participants during the 250–500 ms time bin, t (60) = 9.47, $p < 0.001$, d = 2.45. The group differences on fixation probability for angry faces remained significant during the next two time bins (500–750 ms, t (60) = 7.04, $p < 0.001$, d = 1.82; 750–1000 ms, F (60) = 12.38, $p < 0.001$, d = 3.20). There were no significant differences between the two groups from 1000 to 2000 ms, $ps > 0.05$ (see Fig. 2).

For neutral faces, there was a significant main effect for group, F (1, 60) = 0.01, $p < 0.99$, $\eta_p^2 < 0.01$, suggesting that the SA participants had a higher probability of attending to neutral faces than the NA participants did during the first 2 s. There was no significant interaction of group and time bin, F (7, 420) = 0.94, p = 0.48, $\eta_p^2 = 0.01$. For sad and happy faces, no significant effects involving group were found, $ps > 0.05$. No further analyses were conducted.

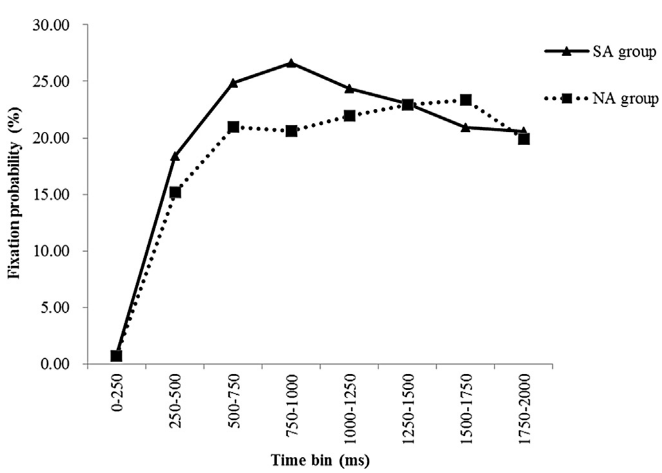

Fig. 2. Fixation probability for angry faces during the first 2 s of presentation.

3.4. Fixation probability during the 10 s presentation time of stimulus

A 2 (group: socially anxious, non-anxious) × 4 (face valence: angry, sad, happy, neutral) × 5 (time bin: 0–2 s, 2–4 s, 4–6 s, 6–8 s, 8–10 s) mixed ANOVA[4] was conducted on fixation probability during the 10 s presentation time. Analyses revealed a significant three-way interaction, F (12, 720) = 1.99, p = 0.02, $\eta_p^2 = 0.03$. To further examine this interaction, separate two-way ANOVAs were then conducted for each face type. For angry faces, there was a significant main effect for group, F (1, 60) = 5.04, p = 0.03, $\eta_p^2 = 0.08$, suggesting that, overall, the SA participants had a higher probability of attending to angry faces than the NA participants during the 10-s presentation time (see Fig. 3a). There was no significant interaction of group and time bin for angry faces, F (4, 240) = 0.75, p = 0.55, $\eta_p^2 = 0.01$.

For happy faces, a significant group × time bin interaction was found, F (4, 240) = 3.91, p = 0.004, $\eta_p^2 = 0.06$. Planned comparisons revealed that no significant difference between the two groups was found during the 0–6 s, $ps > 0.05$. However, the differences between the two groups reached significance during the 6–8 s and 8–10 s time bins, respectively (6–8 s, t (60) = −1.96, p = 0.05, d = 0.51; 8–10 s, t (60) = −2.55, p = 0.01, d = 0.66) (see Fig. 3b). These results suggest that the NA participants had a higher fixation probability for happy faces than the SA participants during the 6–10 s. For sad and neutral faces, no significant effects involving group were found, $ps > 0.05$; thus, no further analyses were conducted.

4. Discussion

The present study is the first study to examine the time-course of sustained attention for multiple competing emotional faces (i.e., four faces) in socially anxious individuals using a free-viewing paradigm. Participants were exposed to an emotional face array composed of angry, sad, happy and neutral faces for 10 s in each trial. Our results showed that the SA participants were not more likely than the NA participants to orient their initial attention toward angry faces. Compared with the NA participants, the SA participants revealed higher fixation probabilities for angry faces during the 250–500, 500–750 and 750–1000 ms time bins. We also found that the SA participants maintained their attention longer than the NA participants did when angry faces were initially fixated upon. These results suggest that the SA participants did not show an initial orienting bias toward threatening faces compared with the NA participants. However, the SA participants revealed increased engagement with threatening faces at an early stage (i.e., 250–500 ms) and continually maintained their attention during the 500–1000 ms after stimulus onset. Moreover, the SA

[3] We also conducted three-way ANCOVAs using the BDI-II scores as a covariate variable. There was a significant three-way interaction, F (21, 1239) = 2.32, $p < 0.001$, $\eta p^2 = 0.04$. To further examine this interaction, separate two-way ANCOVAs were computed for each face type. For angry faces, the group × time bin interaction was significant, F (7, 413) = 4.61, $p < 0.001$, $\eta p^2 = 0.07$. Planned comparisons revealed that the SA participants showed significantly higher fixation probability for angry faces than the NA participants during the 250–500, 500–750, and 750–1000 ms time bins, $ps < 0.05$. For neutral faces, there was a significant main effect for group, F (1, 59) = 5.36, p = 0.02, $\eta p^2 = 0.08$, suggesting that the SA participants had a higher probability of attending to neutral faces than the NA participants did during the first 2 s. There was no significant interaction of group and time bin, F (7, 413) = 1.04, p = 0.40, $\eta p^2 = 0.02$. For sad and happy faces, no significant effects involving group were found, $ps > 0.05$. These results were generally consistent with those from ANOVAs.

[4] We also conducted three-way ANCOVAs using the BDI-II scores as a covariate variable. Analyses revealed a significant three-way interaction, F (12, 708) = 1.97, p = 0.02, $\eta p^2 = 0.03$. Separate two-way ANCOVAs were then conducted for each face type. For angry faces, analyses revealed a significant main effect for group, F (1, 59) = 4.68, p = 0.03, $\eta p^2 = 0.07$, and a non-significant group × time bin interaction, F (4, 236) = 1.43, p = 0.22, $\eta p^2 = 0.02$. The result suggested that, overall, the SA participants had a higher probability of attending to angry faces than the NA participants during the 10-s presentation time. For happy faces, the results revealed a non-significant main effect of group, F (1, 59) = 1.53, p = 0.22, $\eta p^2 = 0.02$, and a significant group × time bin interaction, F (4, 236) = 3.54, p = 0.008, $\eta p^2 = 0.06$. Planned comparisons revealed that no significant difference between the two groups was found during the 0–6 s, $ps > 0.05$. However, the differences between the two groups reached significance and marginally significance during the 6–8 s (p = 0.07) and 8–10 s (p = 0.01) time bins, respectively. For sad and neutral faces, no significant effects involving group were found, ps > 0.05. These results were generally consistent with those from ANOVAs.

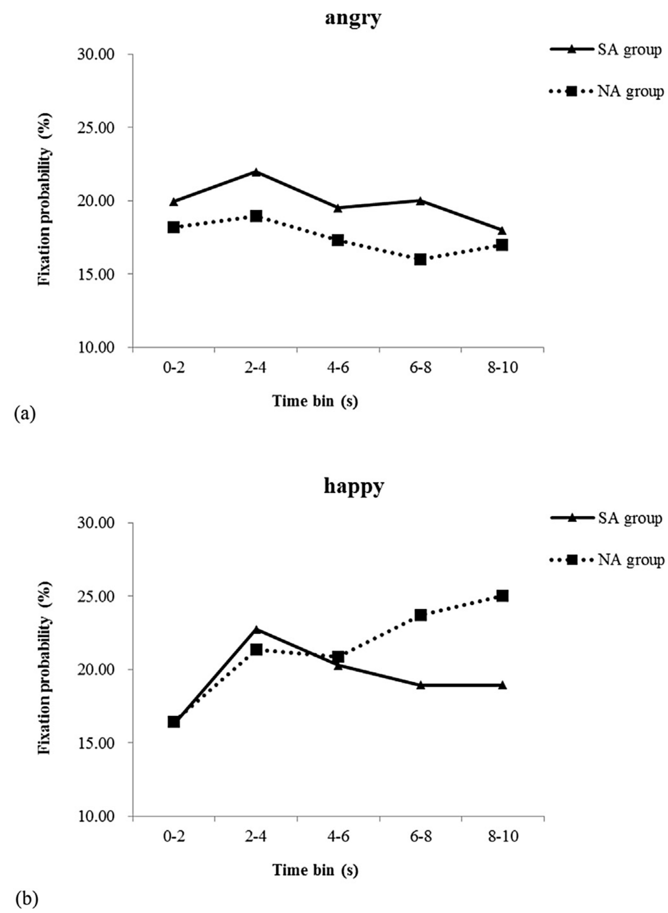

Fig. 3. Fixation probability for angry (a) and happy (b) faces during the 10 s of presentation.

participants showed delayed disengagement from threatening faces, as indicated by a longer gaze duration for initially fixated angry faces. In addition, analyses for the 10 s sustained attention indicates that the NA participants display an overall tendency to preferentially attend to happy faces compared with the SA participants, especially during the late stage of processing (i.e., 6–8 s after stimulus onset).

In previous eye tracking studies, attentional vigilance has been divided into two distinct components: initial orienting and facilitated engagement (Nummenmaa et al., 2006). The initial orienting bias toward threat was inferred from a higher probability of the initial fixation on threatening faces, and facilitated engagement was indexed by a higher fixation probability for threatening faces at an early stage (Armstrong & Olatunji, 2012; Richards et al., 2014). With regard to the initial orienting bias, eye tracking studies using emotional face pairs have found that compared with healthy controls, patients with social phobia direct their initial fixation toward angry faces more than neutral faces (Seefeldt et al., 2014; Stevens et al., 2011). However, the current study failed to provide evidence for initial orienting bias toward threatening faces in individuals with social anxiety. The failure to observe an initial orienting bias toward threatening faces in the current study is consistent with an eye tracking study using a complex array with 16 faces that also did not find evidence for initial orienting bias in social anxiety (Lazarov et al., 2016). One explanation is that the face arrays with four or more faces are more complicated than the face pairs (e.g., neutral-angry) used by previous studies (Seefeldt et al., 2014; Stevens et al., 2011). In the present study, multiple facial expressions (i.e., including positive and negative faces) simultaneously presented are competing for attention, this situation may decrease the relative salience of an angry face to capture anxious participants' attention. In addition, Rinck and Becker (2006) suggested that the magnitude of the observed effect of initial orienting bias may depend on the comparison stimuli which were presented with the threat-related target stimulus. For example, the threat-related target stimulus in our stimulus array was an angry face, and the distractors included three faces with different emotional expressions. The high similarity between the target stimulus and the distractors may have contributed to the lack of initial orienting bias toward threatening stimuli in the current study.

Although our SA participants did not show an initial orienting bias, they exhibited enhanced engagement to threatening faces at an early stage and delayed disengagement form threatening faces compared with the NA participants. Weierich et al. (2008) suggested that anxious individuals tend to pay attention more frequently to threatening stimuli early in viewing and thus have a higher fixation probability at an early stage of processing. Moreover, once a threatening stimulus is attended to, it holds an anxious individual's attention for a period of time and results in delayed disengagement from the threat. The results from our study suggest that socially anxious individuals, compared with non-anxious individuals, may be more likely to attend to threatening stimuli at an early stage and to sustain their attention to threatening stimuli for a period of time. In addition, our results revealed that when the SA participants first fixated on the angry face (but not the other face types), their initial gaze duration for the angry face was longer than that of the NA participants. This result indicates that socially anxious individuals, compared with non-anxious individuals, may exhibit difficulty in disengaging from threatening stimuli when their initial attention is directed toward threatening stimuli. Previous studies using a dot-probe paradigm (Mogg et al., 1997) or a Posner cueing paradigm (Posner, 1980) have provided evidence for difficulty in disengagement from threat in anxious individuals (Amir et al., 2003; Fox, Russo, Bowles, & Dutton, 2001). An eye tracking study using face pair also found evidence for difficulty disengaging from threatening faces (Buckner et al., 2010b). However, the situation created in the current study was more complex than those in previous studies. Our task involved the presentation of multiple emotional expressions, which were employed to simulate an ambiguous social situation containing positive, negative, and neutral information. Thus, the results from the current study suggest that when socially anxious individuals are exposed to a situation containing multiple emotional stimuli (i.e., positive, negative and neutral), they are more likely to allocate their attention to the threatening stimuli at an early processing stage and to show difficulty in disengaging from those stimuli.

To explore the more sustained processing of multiple emotional stimuli in social anxiety, we also examined the time-course of processing over a 10-s trial. We failed to observe attentional avoidance of threatening stimuli at a late stage in the SA participants. In contrast, the results indicated that, overall, the SA participants demonstrated a higher probability than the NA participants to fixate on the angry faces during the 10-s trial. This result is consistent with previous meta-analyses that suggested a significant attentional bias toward threat in anxious individuals (Armstrong & Olatunji, 2012; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Dudeney, Sharpe, & Hunt, 2015). Previous eye tracking research, using complex arrays of facial expressions also showed that socially anxious individuals generally allocated more attention to threatening faces (Buckner et al., 2010a). The results of the current study suggest that socially anxious individuals, compared with non-anxious individuals, may allocate more attention to threatening stimuli throughout the course of processing over a much longer period of time when they are exposed to a situation containing multiple emotional stimuli.

One interesting result of this study is that the NA participants allocated more attention to happy faces than the SA participants did during the 6–10 s after stimuli onset. One explanation for this result is that the NA participants tried to increase their positive affect by purposefully allocating their attention toward happy faces during the late stage of processing for multiple emotional stimuli, whereas the SA participants did not. This result is consistent with previous eye tracking studies that also found evidence for increased attention to happy faces in non-anxious controls, relative to socially anxious individuals (Chen et al., 2012; Schofield et al., 2013). This finding is also consistent with empirical studies that have reported diminished processing of positive information or the absence of positive bias in cognitive processes such as attention, memory, interpretation and expectancy in social anxiety (Garner, Mogg, & Bradley, 2006b; Hirsch & Mathews, 2000; Liang et al., 2011; Taylor, Bomyea, & Amir, 2010). There is growing evidence that socially anxious individuals may experience both fear of positive evaluations and fear of negative evaluations (Weeks & Howell, 2012; Weeks, 2015; Weeks, Heimberg, Rodebaugh, & Norton, 2008; Weeks, Jakatdar, & Heimberg, 2010). Biased processing of positive information in social anxiety may be explained by a fear of positive evaluation (Kashdan, Weeks, & Savostyanova, 2011; Taylor et al., 2010; Weeks et al., 2010). The positive cognitive bias reflects the self-regulatory capacity that facilitates engaging in an activity that would enhance one's positive affect and positive experiences. The lack of positive bias has been proposed to be associated with diminished positive affect and higher reactivity to social stressors in social anxiety (Kashdan et al., 2011; Taylor et al., 2010). The current study suggests that socially anxious individuals lack the positive attentional bias that is observed in non-anxious individuals. Socially anxious individuals may have difficulty in regulating their emotion by purposefully allocating attention toward positive information (Kashdan et al., 2011) and away from negative information (Cisler & Koster, 2010) to increase positive and reduce negative feelings.

Some limitations of the present study must be addressed. First, this study used a non-clinical sample of undergraduate students; therefore, the generalizability of the current findings is limited to individuals with subclinical social anxiety. Second, the stimuli used in the current study were static images of emotional faces which lacked ecological validity. Future studies should use video clips containing complex and dynamic social scenes to improve the ecological validity (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012; Schofield, Weeks, Taylor, & Karnedy, 2015).

In summary, the present study suggests that socially anxious individuals do not show an initial orienting bias toward threats when encountering a situation containing multiple emotional stimuli (i.e., including positive, negative and neutral stimuli). Nevertheless, they show a higher likelihood of attending to threatening stimuli at an early stage of processing and reveal difficulties in disengaging from threatening stimuli once their initial attention is oriented toward those stimuli. This study also indicates that socially anxious individuals are generally more likely to attend to threatening stimuli during the processing of multiple emotional stimuli. Interestingly, non-anxious individuals are more likely to attend to positive stimuli at a very late stage of processing (i.e., 6–8 s after stimuli onset), indicating that non-anxious individuals may purposefully allocate their attention toward positive information in order to regulate their emotion, but this tendency was not observed in socially anxious individuals.

Conflict of interest

No conflict declared.

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