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Attentional control deficits in social anxiety: Investigating inhibition and shifting functions using a mixed antisaccade paradigm

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ABSTRACT

Background and objectives: Attentional control has recently been assumed to play a critical role in the generation and maintenance of threat-related attentional bias and social anxiety. The present study aimed to investigate whether socially anxious (SA) individuals show impairments in attentional control functions, particularly in inhibition and shifting.
Methods: Forty-two SA and 41 non-anxious (NA) participants completed a mixed antisaccade task, a variant of the antisaccade task that is used to investigate inhibition as well as shifting functions.
Results: The results showed that, overall, SA participants had longer antisaccade latencies than NA participants, but the two groups did not differ in their antisaccade error rates. Moreover, in the single-task block, SA participants had longer latencies than NA participants for antisaccade but not prosaccade trials. In the mixed-task block, the SA participants had longer latencies than the NA participants for both task types. The two groups did not differ in their latency switch costs in the mixed-task blocks.
Limitations: First, this study was conducted using a non-clinical sample of undergraduate students. Second, the antisaccade task measures primarily oculomotor inhibition. Third, this study did not include the measure of state anxiety to rule out the effects of state anxiety on the present findings.
Conclusions: This study suggests that SA individuals demonstrate diminished efficiency of inhibition function but show no significant impairment of shifting function. However, in the mixed-task condition, SA individuals may exhibit an overall reduction in processing efficiency due to the higher task difficulty.

1. Introduction

Cognitive theories suggest that social anxiety results from information processing biases of socially threatening stimuli such as attentional, memory, and interpretive biases (Clark & McManus, 2002; Heinrichs & Hofmann, 2001). Increasing evidence supports the hypothesis that socially anxious (SA) individuals (i.e., individuals with social anxiety disorders or individuals with subclinical social anxiety) show attentional bias toward threatening stimuli (e.g., threatening faces) (Bantin, Stevens, Gerlach, & Hermann, 2016; Staugaard, 2010). More specifically, some studies have shown that SA individuals exhibited attentional vigilance toward threatening stimuli (Klumpp & Amir, 2009; Mogg, Philippot, & Bradley, 2004; Pishyar, Harris, & Menzies, 2004), while others have shown that they had difficulty in disengagement from threatening stimuli (Amir, Elias, Klumpp, & Przeworski, 2003; Buckner, Maner, & Schmidt, 2010; Liang, Tsai, & Hsu, 2017). In recent years, considerable attention has been focused on the mechanisms underlying attentional bias in anxiety (Cisler & Koster, 2010). On the one hand, some researchers suggest that attentional control may moderate the relationship between social anxiety and attentional bias. For example, one study reported that SA individuals with poor self-reported attentional control ability showed more difficulty disengaging from threats than those with better self-reported attentional control ability (Taylor, Cross, & Amir, 2016). On the other hand, some researchers suggest that attentional bias for threatening stimuli may result from impaired attentional control ability (Heeren, De Raedt, Koster, & Philippot, 2013). From this perspective, SA individuals are assumed to exhibit attentional control deficits and these deficits may lead to threat-related attentional bias (Cisler & Koster, 2010). Functional neuroimaging studies have reported that SA individuals had reduced recruitment of the dorsolateral prefrontal cortex (DLPFC) and dorsal anterior cingulate cortex (DLACC), which are involved in top-down attentional control processes (Balderston et al., 2017; Blair et al., 2012). These findings lead to the important question of whether SA individuals exhibit general attentional control difficulties compared with non-anxious (NA) individuals.

Attentional control refers to the ability to efficiently and flexibly allocate attention to goal-relevant information and resist interference

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from goal-irrelevant information (Eysenck, Derakshan, Santos, & Calvo, 2007). Attentional control theory (ACT) was developed by Eysenck et al. (2007) to explain the negative effects of anxiety on cognitive performance via attentional control processes. According to ACT, the term "anxiety" is used here to refer to both individual differences in anxiety (e.g., trait anxiety or social anxiety) and state anxiety which is experimentally manipulated (e.g., via evaluative instructions). There are two major assumptions underlying ACT. The first assumption is that anxiety impairs attentional control and leads to poor performance on tasks involving two core central executive functions, inhibition and shifting (Miyake et al., 2000). Successful attentional control processes rely on a balanced interaction between a stimulus-driven attentional system and a goal-directed attentional system (Corbetta & Shulman, 2002). The stimulus-driven attentional system involved in the bottom-up control of attention was found to be primarily influenced by the salience of a stimulus. It is also involved in a threat-detection mechanism that is associated with amygdala activity (Cisler & Koster, 2010; Mogg & Bradley, 2016). The goal-directed attentional system involved in the top-down control of attention was found to be mainly influenced by an individual's current goals. ACT assumes that anxious individuals[1] tend to allocate greater attentional resources to detect the potential threatening stimuli in the environment, and thus, the amount of attentional resources devoted to task-relevant stimuli is reduced. Therefore, ACT proposes that anxiety impairs attentional control processes by interfering with the balance between the two attentional systems. Specifically, anxiety leads to an increased influence of the stimulus-driven attentional system and a decreased influence of the goal-directed attentional system (Eysenck et al., 2007). This assumption can be used to account for the mixed findings regarding threat-related attentional biases in SA individuals. On the one hand, some studies reported that SA individuals exhibited facilitated attention for threats (Klumpp & Amir, 2009; Stevens, Rist, & Gerlach, 2009), which has been assumed to be associated with increased stimulus-driven bottom-up processing. On the other hand, other studies showed that SA individuals demonstrated difficulty in disengaging from threats (Amir et al., 2003; Moriya & Tanno, 2011), which has been assumed to be associated with diminished goal-directed top-down attentional control (Cisler & Koster, 2010). Accordingly, ACT predicts that anxious individuals demonstrate impairments in two critical central executive functions, inhibition and shifting, which are directly involved in attentional control. The inhibition function refers to an ability to resist interference from task-irrelevant stimuli and suppress irrelevant prepotent responses when necessary. The shifting or set-shifting function refers to the capacity to flexibly switch one's attention back and forth between different tasks or response rules.

The second assumption of ACT is that anxiety adversely impacts processing efficiency more than performance effectiveness. Effectiveness refers to one's ability to make responses correctly on a task. Efficiency, by contrast, refers to the amount of cognitive resources one devotes to performing a task correctly. Decreased performance effectiveness of a task is usually indexed by lower response accuracy, while reduced processing efficiency is usually indexed by longer response latency (Ansari, Derakshan, & Richards, 2008). According to ACT, anxious individuals may try to compensate for the adverse effects of anxiety by making more efforts to achieve the task goal. Therefore, ACT predicts that anxious individuals may exhibit reduced processing efficiently but show intact performance effectiveness on tasks involving inhibition and shifting functions compared with NA individuals (Eysenck & Derakshan, 2011; Eysenck et al., 2007).

Researchers have used a variety of experimental tasks to investigate attentional control functions in anxious individuals. For example, the Stroop task, in which participants are required to ignore the word content and report the printed ink color of each word as fast as possible (Price & Mohlman, 2007) was used to measure inhibition function, and the Wisconsin Card Sorting Test (WCST) which is a neurological test of "set-switching" was used to measure shifting function (Caselli, Reiman, Hentz, Osborne, & Alexander, 2004). However, these tasks do not provide a direct measurement of attention. Eye tracking has recently become a promising technology to provide a more direct assessment of attentional control and has been increasingly applied to investigate human cognitive processes (Ainsworth & Garner, 2013; Eckstein, Guerra-Carrillo, Miller Singley, & Bunge, 2017). The antisaccade task, an eye tracking paradigm that assesses the top-down attentional control, has been widely used in studies of a variety of psychiatry disorders (Ainsworth & Garner, 2013; Malsert et al., 2012; Rommelse, Van der Stigchel, & Sergeant, 2008). In the antisaccade task, participants are instructed to make either a prosaccade toward or an antisaccade away from a sudden onset target. When a target suddenly appears in the peripheral visual field, individuals have a natural tendency to make a reflexive prosaccade toward and fixate on it. By contrast, antisaccades require participants to inhibit a reflexive prosaccade toward the suddenly appearing target and to generate a voluntary saccade in the opposite direction. Pro-and antisaccades are often completed in separate single-task blocks of trials with either all prosaccades or all antisaccades during a typical antisaccade task. The antisaccade task provides two measures to evaluate participants' attentional inhibition ability. The error rates of antisaccade trials are used to index performance effectiveness, and the latencies of correct antisaccades are used to index processing efficiency. Several studies have shown that compared with low-anxious individuals, individuals with high trait anxiety demonstrated intact performance effectiveness but impaired processing efficiency on an antisaccade task involving inhibition (Ainsworth & Garner, 2013).

Some researchers have used the mixed antisaccade task, a variant of the antisaccade task, to investigate inhibition as well as shifting functions involved in attentional control (Ansari et al., 2008; De Lissnyder, Derakshan, De Raedt, & Koster, 2011). There are two kinds of experimental blocks: single-task blocks, in which only pro- or only antisaccade trials are included, and mixed-task blocks, in which pro- and antisaccade trials are interspersed randomly. In the mixed-task blocks, participants are required to flexibly switch between pro- and antisaccade task rules. Therefore, the mixed antisaccade tasks can be used to assess both inhibition and shifting functions. Ansari et al. (2008) investigated participants' performance on a mixed antisaccade task and reported that individuals with high trait anxiety showed less efficient inhibition and shifting functions than individuals with low trait anxiety. To date, few studies have simultaneously examined inhibition and shifting functions in individuals with high social anxiety. One study of event-related potential (ERP) activity in the mixed antisaccade task by Judah, Grant, Mills, and Lechner (2013) reported that SA individuals showed impaired processing efficiency for both inhibition and shifting. Moreover, their findings suggest that self-focused attention may exaggerate these deficits. However, the mixed antisaccade task used in their study included only mixed-task blocks (pro- and antisaccade trials were interspersed randomly), not single-task blocks (only pro- or only antisaccade trials). This may result in difficulty in differentiating inhibition from shifting abilities in the task (Fox, Derakshan, & Standage, 2011). More empirical investigations are necessary to clarify whether SA individuals exhibit impairments in both inhibition and shifting functions.

The present study attempted to adopt the mixed antisaccade task to simultaneously investigate inhibition and shifting in SA individuals. The Brief Fear of Negative Evaluation scale (BFNE; Leary, 1983) was used for screening of SA and NA participants because cognitive models have postulated that fear of negative evaluation is a core feature of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997). The

[1] ACT (Eysenck et al., 2007) emphasizes adverse effects of anxiety on processing efficiency. The term "anxiety" in ACT is used to refer to both individual differences in anxiety (e.g., trait anxiety or social anxiety) and state anxiety. Accordingly, "anxious individuals" here is used as a generic term for both individuals with high trait anxiety (or other more specific measures such as high social anxiety) and individuals with high state anxiety.

BFNE has been used in previous studies to select participants with subclinical social anxiety (George & Stopa, 2008; Schofield, Coles, & Gibb, 2007; Wieser, Pauli, & Muhlberger, 2009). Although ACT suggests that state anxiety also impairs attentional control, the current study focused on examining the effects of trait social anxiety (Moriya & Sugiura, 2012) rather than state social anxiety (currently experienced levels of social fear) on attentional control. Trait social anxiety refers to an individual's tendency to experience fear and anxiety in social situations (Leary & Kowalski, 1995). Individuals with greater trait social anxiety tend to experience higher state social anxiety when encountering social situations. Therefore, the current study did not intend to induce state social anxiety (e.g., by public speaking task) in participants. In sum, the aim of the current study was to examine whether individuals with high trait social anxiety (i.e., particularly with high levels of fear of negative evaluation) exhibit impaired attentional control. Our predictions were as follows: First, we predicted that SA individuals would show impaired inhibition efficiency, indicated by longer antisaccade latencies, compared with NA individuals. Second, we predicted that SA individuals would demonstrate impaired efficiency in shifting functions as indicated by larger switch costs. The switch cost was defined as the mean saccade latency difference between the switched trial, which was preceded by the opposite type of task (i.e., antisaccade-prosaccade or prosaccade-antisaccade), and the repeated trial, which was preceded by the same type of task (i.e., antisaccade-antisaccade or prosaccade-prosaccade) in the mixed-task block. Third, we predicted that SA and NA individuals would not differ in performance effectiveness of inhibition and shifting functions.

2. Materials and methods

2.1. Participants

A total of 1105 Taiwanese undergraduates who were enrolled in the elective courses at a university in Taiwan completed a screening scale, the BFNE. The undergraduates who scored in the highest quartile (BFNE≧40) and scored below the mean (BFNE≦35) were defined as the SA and NA individuals, respectively. Potential participants were contacted via an e-mail and invited to participate in our study. Forty-two SA (28 females; $M_{age} = 20.79$, $SD = 1.73$) and forty-one NA (32 females; $M_{age} = 20.90$, $SD = 1.32$) individuals volunteered to participate in this study. The experiment was conducted in the Eye Movement Laboratory at a university in Taiwan.

Because the BFNE may be criticized that it measures fear of negative evaluation rather than social anxiety, the Social Interaction Anxiety Scale (SIAS; Mattick & Clarke, 1998) which is another commonly used instrument measuring social anxiety was also included to evaluate participants' levels of social interactional anxiety in the present study. The mean BFNE score for the SA group in this study ($M = 48.00$, $SD = 4.71$) was similar to the mean scores in patients with social phobia from previous studies (ranging from 46.91 to 51.50); the mean BFNE score for the NA group in this study (M = 27.80, SD = 3.50) was similar to the mean scores in community samples groups from previous studies (ranging from 26.81 to 29.2) (Collins, Westra, Dozois, & Stewart, 2005; Weeks et al., 2005). The mean SIAS score for the SA group in this study ($M = 40.93$, $SD = 11.97$) was similar to the mean scores in patients with social phobia from previous studies (ranging from 34.6 to 47.17) (Mattick & Clarke, 1998; Rodebaugh, Woods, Heimberg, Liebowitz, & Schneier, 2006); the mean SIAS score for the NA group in this study ($M = 26.85$, $SD = 10.94$) was similar to the mean scores in community samples groups from previous studies (ranging from 22.72 to 31.22) (Carter, Sbrocco, Tang, Rekrut, & Condit, 2014; Zubeidat, Salinas, Sierra, & Fernández-Parra, 2007). SA participants showed higher levels of social anxiety as measured by the BFNE, $t(81) = 22.12$, $p < .001$, and the SIAS, $t(81) = 5.59$, $p < .001$.

Moreover, because previous studies suggested that depression is associated with impaired attentional control (reviewed by Ainsworth & Garner, 2013), participants also completed the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996), which assesses the severity of depression. SA participants had higher BDI-II scores, $t(81) = 3.13$, $p < .001$, than NA participants. A preliminary analysis was performed to examine the correlations between the BDI-II scores and all dependent variables. The BDI-II was significantly correlated with correct antisaccade latencies, $r = 0.218$, $p = .04$, and with correct antisaccade latencies for repeated trials in the mixed-task block, $r = 0.216$, $p < .04$. No other correlations were significant (all $ps > .05$). Therefore, BDI-II was included as a covariate in all analyses in the present study. No differences were found in mean age, $t(81) = -0.35$, $p = .73$, or gender ratio, $\chi^2(1, N = 83) = 1.34$, $p = .25$. Characteristics of the participants are shown in Table 1.

Table 1
Mean and standard deviation for group characteristics.

	SA group (n = 42)		NA group (n = 41)	
	M	*SD*	*M*	*SD*
Age	20.79	1.73	20.90	1.32
BFNE	48.00	4.71	27.80	3.50
SIAS	40.93	11.97	26.85	10.94
BDI-II	12.12	8.72	6.83	6.51

Note: SA group = socially anxious group; NA group = non-anxious group; BFNE = Brief Fear of Negative Evaluation Scale; SIAS = Social Interaction Anxiety Scale; BDI-II = Beck Depression Inventory-II.

2.2. Self-report inventories

The BFNE is a 12-item scale measuring an individual's worries about receiving a negative evaluation from others. The SIAS is a 20-item scale assessing an individual's affective, cognitive, and behavioral reactions to interactional situations. The BDI-II is a 21-item scale evaluating the severity of depressive symptoms. The Chinese version of each scale has been found to possess acceptable internal consistency (BFNE, α = 0.87; SIAS, α = 0.89; BDI-II, α = 0.86-0.89) and construct validity (Chang, 2005; Chen, 2000; Liang, Hsu, Hung, & Wang, 2012; Liang, Hsu, Hung, Wang, & Lin, 2011). All these scales have good internal consistencies (BFNE, α = 0.87; SIAS, α = 0.88; BDI-II, α = 0.90) in the present study.

2.3. Mixed antisaccade task

A mixed antissaccade task, similar to the one adopted by De Lissnyder et al. (2011) was used in the study. This task comprised 2 types of task blocks: single-task blocks (all prosaccades or all antisaccades) and mixed-task blocks (prosaccades and antisaccades were presented randomly). Participants completed 8 blocks (4 blocks for each block type) of 8 practice trials (64 practice trials in total) and 36 experimental trials (288 experimental trials in total). At the beginning of each block, an instruction was displayed on the screen to indicate the type of block (a single- or mixed-task block). For a single-task block, the instruction also indicated the type of task (pro- or antisaccade task). Each trial started with the presentation of a central fixation point (subtending 0.6°) for a random interval between 800 and 1200 ms with an average of approximately 1000 ms. Participants were instructed to look at the fixation point until it disappeared. After the central fixation point disappeared, a cue was presented on the center of the screen for 300 ms, followed by a 200-ms blank screen. Then, an oval-shaped target (3.3° × 6°) appeared at an 11° visual angle to either the left or the right side of the screen for 600 ms. Participants were required to either fixate on the target (prosaccade) or direct their gaze away from it and toward its mirror position on the screen (antisaccade). In single-task blocks, the cue was a white cross (2° × 2°). In mixed-task blocks, the cue was either a diamond (1.2° × 2.4°) or a circle (1.7° diameter), indicating prosaccade and antisaccade, respectively. The order of single- (A) and mixed-task (B) blocks was counterbalanced across subjects as follows: ABABABAB or BABABABA. The order of pro- (A) and antisaccade (B) trials in the single-task blocks was counterbalanced across subjects as follows: ABAB or BABA.

2.4. Apparatus

Eye movements were recorded via the desktop-mounted EyeLink 1000 Plus eye-tracking system (SR Research Ltd, Mississauga, Canada), a video-based eye tracking system. The EyeLink 1000 Plus uses pupil center corneal reflections to record monocular gaze position at 1000 Hz (1000 samples per second), with up to 0.25° accuracy and 0.01° spatial resolution. The mixed antisaccade task was created using SR Research Experiment Builder and presented on a 17-inch LCD monitor with a resolution of 1024 × 768 pixels and a refresh rate of 60 Hz.

2.5. Procedure

Following informed consent, participants read written instructions about the experimental task. Then, they were seated in front of the monitor, and the chin and forehead rest were used to restrain their head movements. The distance between the participant's eye and the screen was 60 cm. After a 9-point calibration, participants performed the mixed antisaccade task. Finally, all participants completed the BFNE, SIAS, and BDI-II. Participants received NTD$300 (equivalent to US$10 dollars) as compensation for their time. The procedures were approved by the Research Ethics Committee of National Taiwan University.

2.6. Data preparation and statistical analyses

Eye movement data were analyzed using Data Viewer (SR Research Ltd, Mississauga, Canada). We examined two dependent variables: saccade error rate and latency of correct saccade. Saccade onset was detected when saccade velocity and acceleration exceeded 30°/s and 8000°/s^2, respectively. Saccade errors were identified as trials in which the first saccade was towards the target (on antisaccade trials) or in the opposite direction of the target (on the prosaccade trials). Saccade latencies were defined as the elapsed time between the onset of the target and the initiation of correct saccade. Trials were discarded if (1) the data recording was interrupted because of lost pupil or corneal reflectance, (2) if there was a blink before the saccade (Jazbec, McClure, Hardin, Pine, & Ernst, 2005), or (3) the latency of the first saccade was shorter than 80 ms (i.e., anticipatory saccade, Fischer & Weber, 1992) or longer than 600 ms (Ansari & Derakshan, 2010). These criteria resulted in the loss of 4.22% of the antisaccade and 4.33% of the prosaccade trials in the single-task blocks, and 4.69% of the antisaccade and 4.31% prosaccade trials in the mixed-task blocks.

The latencies of correct saccades and saccade error rates were analyzed by mixed analyses of covariance (ANCOVAs) with the group (SA or NA) as a between-subjects factor and task type (antisaccade or prosaccade) and block type (single-task or mixed-task) as within-subjects factors, while controlling for the BDI-II scores. To further examine participants' switching performance, we divided the trials within the mixed-task block into switched and repeated trials. The latencies of correct saccades in the mixed-task block were analyzed by a mixed ANCOVA with the group (SA or NA) as a between-subjects factor and task type (antisaccade or prosaccade) and trial type (switched or repeated) as within-subjects factors while controlling for the BDI-II score. The switch costs (mean latency in switch trials minus mean latency in repeated trials) in the mixed-task block were analyzed by a two-way mixed ANCOVA with the group (SA or NA) as a between-subjects factor and task type (antisaccade or prosaccade) as a within-subjects factor while controlling for the BDI-II score.

3. Results

3.1. Error rate

The results revealed that the main effect of BDI-II (covariate) was not significant, F (1, 80) = 0.26, p = .61, η_p^2 < 0.01, and interaction effects involving BDI-II were not significant (ps > .05). After controlling for the effect of depression, the main effects of task type was significant, F (1, 80) = 36.89, p < .001, η_p^2 = 0.32. Participants had greater error rates on the antisaccades than on the prosaccades. The main effect of block type was not significant, F (1, 80) = 2.67, p = .11, η_p^2 = 0.03. The main effect of group was also not significant, F (1, 80) = 0.90, p = .34, η_p^2 = 0.01. No significant interactions were found.

3.2. Latencies of correct saccades

The results revealed that the main effect of BDI-II was not significant, F (1, 80) = 0.78, p = .38, η_p^2 = 0.01, and interaction effects involving BDI-II were not significant (ps > .05). After controlling for the effect of depression, the results showed significant main effects of task type, F (1, 80) = 114.27, p < .001, η_p^2 = 0.59, and block type, F (1, 80) = 21.54, p < .001, η_p^2 = 0.21. Participants demonstrated longer correct saccade latencies on the antisaccades than on the prosaccades (see Table 2). Similarly, they had longer correct saccade latencies in the single-task block than in the mixed-task block. The main effect of group also reached significance, F (1, 80) = 7.33, p = .008, η_p^2 = 0.08. SA participants had longer correct saccade latencies than NA participants did. The task type × block type interaction was significant, F (1, 80) = 39.39, p < .001, η_p^2 = 0.33, indicating that participants had slower saccade latencies in the mixed-task block than in the single-task block for antisaccade trials but not for prosaccade trials. However, this interaction was further qualified by a significant three-way interaction, F (1, 80) = 5.88, p = .019, η_p^2 = 0.07. This interaction indicated that, for the single-task block, SA participants had longer antisaccade but not prosaccade latencies than NA participants (antisaccade, F (1, 80) = 7.42, p = .008, η_p^2 = 0.09; prosaccade, F (1, 80) = 1.47, p = .22, η_p^2 = 0.01). For the mixed-task block, SA participants had longer correct saccade latencies for both antisaccade and prosaccade trials (antisaccade, F (1, 80) = 4.81, p = .03, η_p^2 = 0.06; prosaccade, F (1, 80) = 7.09, p = .009, η_p^2 = 0.08) (see Fig. 1).

3.3. Latencies of correct saccades for switched and repeated trials in the mixed-task block

No significant main effect of BDI-II was found, F (1, 80) = 0.43, p = .51, η_p^2 < 0.01, and no significant interaction effects involving BDI-II were found (ps > .05). After controlling for the effect of depression, the results revealed a significant main effect of task type, F (1, 80) = 62.33, p < .001, η_p^2 = 0.44, indicating that, overall, participants demonstrated longer correct saccade latencies on the antisaccades than on the prosaccade task in the mixed-task block. The main effect of group was significant, F (1, 80) = 7.01, p = .01, η_p^2 = 0.08, indicating

Table 2
Mean and standard deviation for latencies of correct saccades.

	SA group (n = 42)		NA group (n = 41)	
	M	*SD*	*M*	*SD*
Single-task block				
Antisaccade	269.68	36.24	246.75	27.14
Prosaccade	198.42	21.40	191.88	18.40
Mixed-task block				
Antisaccade	243.98	31.78	225.87	29.97
Prosaccade	202.34	22.73	188.57	21.30

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

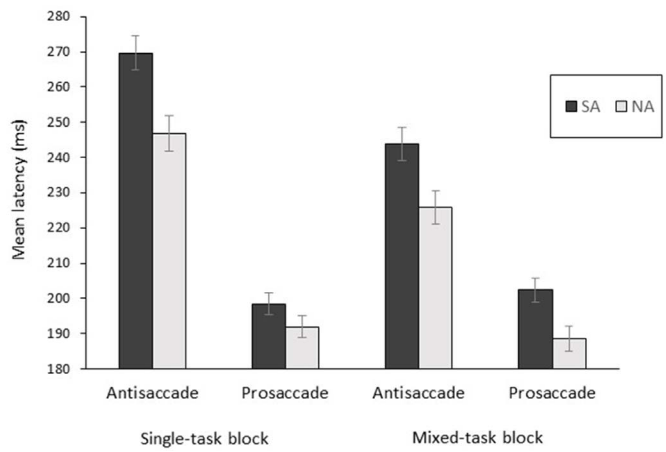

Fig. 1. Mean antisaccade and prosaccade latencies for single-task and mixed-task blocks (error bars represent standard errors of the mean).

that SA participants had longer saccade latencies than NA participants. The task type × trial type interaction also reached significance, F (1, 80) = 8.33, p = .005, $\eta_p^2 = 0.09$. This interaction showed that participants had longer prosaccade latencies for the switched trials than for the repeated trials, F (1, 81) = 7.13, p = .009, $\eta_p^2 = 0.08$. However, there was no significant difference between the antisaccade latencies of the two trial types, F (1, 81) = 2.76, p = .10, $\eta_p^2 = 0.03$. No other significant main effect or interactions were found.

With regard to the switch costs, the results showed that the main effect of BDI-II was not significant, F (1, 80) = 0.53, p = .47, $\eta_p^2 < 0.01$, and interaction effects of task type × BDI-II was also not significant, F (1, 80) = 0.59, p = .44, $\eta_p^2 < 0.01$. After controlling for the effect of depression, the main effect of group was not significant, F (1, 80) = 0.03, p = .85, $\eta_p^2 < 0.001$. The group × task type was also not significant, F (1, 80) = 0.04, p = .83, $\eta_p^2 < 0.001$.

4. Discussion

The present study aimed to investigate whether SA individuals demonstrate impairments in attentional control (i.e., inhibition and shifting) using the mixed antisaccade task. According to a prediction of ACT, anxiety impedes an individual's central executive functions, especially inhibition and shifting (Eysenck et al., 2007). Thus, we predicted that SA participants might have poorer performance than NA participants on the mixed antisaccade task, which is a well-developed and commonly used task measuring attentional control (Ainsworth & Garner, 2013; De Lissnyder et al., 2011). Our results showed that SA participants had longer antisaccade latencies than NA participants, but the two groups did not differ in their antisaccade error rates. Reduced antisaccade performance has been assumed to result from a diminished ability to inhibit the reflexive orienting to an abrupt but task-irrelevant stimulus (Ansari & Derakshan, 2010). Slower latencies and higher error rates for antisaccades respectively reflect diminished efficiency and effectiveness of attentional inhibition. Thus, our findings suggest that compared with NA individuals, SA individuals demonstrate inhibition deficits by showing reduced performance efficiency, but not performance effectiveness, when they are required to make an antisaccade response. The impaired voluntary control of attention might be associated with reduced activity in the DLPFC, which is assumed to be involved in top-down attentional control processes (Bishop, 2009; Koval, 2012; Li et al., 2017; Matsuda et al., 2004). Previous studies have found that attentional control can modulate attentional biases for threats (Derryberry & Reed, 2002; Peers & Lawrence, 2009). Accordingly, attentional control has been assumed to play a critical role in the development and maintenance of threat-related attentional bias (Heeren et al., 2013).

According to ACT, anxiety influences attentional control system by increasing the influence of stimulus-driven attentional system as well as decreasing the influence of goal-directed attentional system. When a task-irrelevant threatening stimulus is present, anxious individuals (e.g., SA individuals) may show facilitated attentional engagement toward the threatening stimulus (i.e., attentional vigilance toward threats) due to the enhanced activity of the stimulus-driven attentional system, thereby decreasing functioning of the goal-directed attentional system and resulting in impaired top-down attentional control, particularly inhibition and shifting. Consequently, anxious individuals may have difficulties in voluntarily directing their attention away from a task-irrelevant threatening stimuli and toward a task-relevant stimuli (i.e., difficulties in disengagement from threats). Furthermore, even when no task-irrelevant threatening stimulus is present, ACT predicts that anxious individuals will widely allocate attention to detect potentially threatening stimuli, thereby reducing the top-down attentional control. As a result, they will exhibit impaired attentional control, even when a threatening stimulus is not present. The present findings indicates that SA individuals demonstrate diminished efficiency of inhibition function compared with NA individuals, even in the absence of socially threatening stimuli. Because the current study did not include threatening stimuli and measures of attentional bias, we cannot examine the relationships between different components of attentional bias and attentional control in SA individuals. In addition, a recent research suggests that the mechanisms underlying social anxiety might be considered a complex dynamic system involving mutually interacting variables such as attentional control, attentional bias, emotional vulnerability and symptoms of social anxiety (Heeren & McNally, 2016). Therefore, future research should include not only attentional bias and attentional control but also other related variables to clarify the relationships between these variables.

Our results were consistent with the prediction of ACT suggesting that anxiety impairs processing efficiency more than performance effectiveness. Similar results have also been reported in individuals with high trait anxiety in previous studies (Ansari & Derakshan, 2010; Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009). However, researchers used an emotional version of the antisaccade task and observed that anxious individuals showed an opposite pattern (Garner, Ainsworth, Gould, Gardner, & Baldwin, 2009; Wieser et al., 2009). For example, a study by Wieser et al. (2009) reported that SA individuals showed a higher antisaccade error rate for emotional faces than NA individuals did, regardless of valence, but no group differences were found in their pro- and antisaccade latencies. The authors interpreted the results as indicating that facial expressions might be perceived as highly threatening and emotionally salient by SA individuals. Consequently, SA individuals showed greater performance impairment, indicated by diminished effectiveness (i.e., unable to make correct responses) rather than reduced efficiency (i.e., longer latencies), when performing antisaccades for emotional faces.

In addition to the efficiency of inhibition function, ACT assumes that anxiety impairs the efficiency of the shifting function (Eysenck et al., 2007). To investigate the efficiency of the shifting function in SA individuals, we compared the differences between groups in their latencies for switched and repeated trials in the mixed-task block. The results showed that, overall, SA participants had longer saccade latencies than NA participants, but the group differences did not vary across different task types (anti- or prosaccade) or trial types (switched or repeated). Moreover, switch costs did not significantly differ between groups. These results suggested no impairment in shifting in SA individuals. However, our results also showed that, in the single-task block, SA participants had longer latencies for antisaccades but not prosaccades than NA participants, while in the mixed-task block, the SA participants had longer latencies for both task types than the NA participants. These findings indicated that when SA participants were required to switch between two tasks, they generally spent more time than NA participants making a correct saccade not only for antisaccades but also for prosaccades which were assumed to be rapid reflexive responses. The present study suggests that compared with NA individuals, SA individuals demonstrate an overall reduction in processing efficiency (longer response latencies) under the condition that involved shifting between two task rules.

An alternative explanation for these findings is that SA participants had longer saccade latencies for both anti- and prosaccade trials in the mixed-task block due to higher cognitive load rather than deficits in shifting. In the mixed-task block, participants had to determine which saccade direction (anti- or prosaccade) they were required to move according to the cue (circle or diamond) that was followed by the target. This relatively complex task condition increased cognitive load, which resulted in a reduced overall efficiency in SA participants relative to NA participants. Previous research has shown that individuals with high social anxiety exhibit a decreased overall processing efficiency relative to individuals with low social anxiety individuals under high cognitive load (Soares, Rocha, Neiva, Rodrigues, & Silva, 2015). Judah, Grant, Lechner, and Mills (2013) also reported that high working memory load leads to poor attentional control in socially anxious individuals. Moreover, because participants were required to remember and switch between the rules (diamond = prosaccade and circle = antisaccade) in the mixed-task blocks, the process of working memory updating might also be required to complete this task successfully. Therefore, it is possible that deficits in working memory updating in socially anxious individuals also contribute to these findings. More studies may be needed to examine whether socially anxious individuals exhibit general deficits in working memory updating ability.

The findings of the present study may have important implications for interventions for social anxiety. Since socially anxious individuals showed impaired inhibition efficiency, interventions aimed at enhancing attentional inhibition function may be beneficial for individuals with social anxiety to reduce difficulties in disengagement from threats. This suggestion is consistent with the assumption that inefficient attentional control may contribute to maintain attentional bias (Heeren et al., 2013). A novel treatment approach using the antisaccade task as a training tool has been developed to enhancean individual's attentional inhibition (Giel, Schag, Plewnia, & Zipfel, 2013). In addition, the present study indicated that socially anxious individuals showed an overall reduction in processing efficiency under high cognitive load. It is possible that improving working memory capacity would be helpful in overcoming the negative effect of trait social anxiety on attentional control, particularly under high cognitive load (Wright, Dobson, & Sears, 2014). Working memory training has been shown to be effective in enhancing attentional control in trait anxious individuals (Sari, Koster, Pourtois, & Derakshan, 2016).

This study has some limitations. First, because this study was conducted using a non-clinical sample of undergraduate students, the generalizability of the current results is limited to individuals with subclinical social anxiety. Second, the antisaccade task measures primarily oculomotor inhibition, which refers to one's ability to suppress their reflexive saccades toward an abrupt-onset target. Nevertheless, inhibition functions also include other processes such as interference control and behavioral inhibition, which have been identified in previous studies (Nigg, 2000). Although Miyake et al. (2000) suggested that these processes involve the same underlying inhibition function, some evidence has shown that oculomotor inhibition and behavioral inhibition are anatomically and functionally separate processes (Aron, Robbins, & Poldrack, 2004; Nigg, 2000). Future studies should include measures of different inhibition processes and explore the relationships between these processes and social anxiety. Third, this study did not include the measure of state anxiety, thus it is difficult to rule out the effects of state anxiety on the present findings. Although the present study did not try to experimentally induce state anxiety in participants, SA participants may be expect to experience higher levels of anxiety than NA participants in an unfamiliar setting (i.e., in the laboratory). Future studies should include the measure of state anxiety to clarify the effects of state and trait social anxiety and their interaction on attentional control.

In conclusion, the present study suggests that SA individuals spend more time than NA individuals inhibiting a reflexive prosaccade toward the target and making a correct antisaccade, indicating that SA individuals demonstrate diminished efficiency in their inhibition function. However, this study indicates that there is no obvious evidence for the impairment of the shifting function in SA individuals. The results suggest that SA individuals have longer saccade latencies for both anti- and prosaccade trials in the mixed-task blocks, indicating that SA individuals may exhibit a reduced overall processing efficiency due to higher cognitive load.

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