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Attentional Bias to Emotional Stimuli and Effects of Anxiety on the Bias in Neurotypical Adults and Adolescents

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Abstract

Human can rapidly detect and deal with dangerous elements in their environment, and they generally manifest as attentional bias toward threat. Past studies have reported that this attentional bias is affected by anxiety level. Other studies, however, have argued that children and adolescents show attentional bias to threatening stimuli, regardless of their anxiety levels. Few studies directly have compared the two age groups in terms of attentional bias to threat, and furthermore, most previous studies have focused on attentional capture and the early stages of attention, without investigating further attentional holding by the stimuli. In this study, we investigated both attentional bias patterns (attentional capture and holding) with respect to negative emotional stimulus in neurotypical adults and adolescents. The effects of anxiety level on attentional bias were also examined. The results obtained for adult participants showed that abrupt onset of a distractor delayed attentional capture to the target, regardless of distractor type (angry or neutral faces), while it had no effect on attention holding. In adolescents, on the other hand, only the angry face distractor resulted in longer reaction time for detecting a target. Regarding anxiety, state anxiety revealed a significant positive correlation with attentional capture to a face distractor in adult participants but not in adolescents. Overall, this is the first study to investigate developmental tendencies of attentional bias to negative facial emotion in both adults and adolescents, providing novel evidence on attentional bias to threats at different ages. Our results can be applied to understanding the attentional mechanisms in people with emotion-related developmental disorders, as well as typical development.

Key words: Attentional Bias, State Anxiety, Trait Anxiety, Adolescents, Emotional Facial Expression

1. INTRODUCTION

Attention is the essential component at the initial stage of cognitive process to select important information which will be transferred to higher cognitive levels (Atkinson & Shiffrin, 1968). In terms of survival, attentional function has evolved to effectively detect threatening information in the environment (Mogg & Bradley, 1998; Öhman, 1996). Indeed, previous studies have reported that negative emotional stimuli affected attentional processing significantly resulting in an attentional bias. For example, Waters et al. (2004) found that

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neuro-typical children and adults reacted to fearful pictures significantly faster than to neutral pictures. However, attentional process is not a simple process and need to consider several factors together, including distractor/context, anxiety, and age.

For instance, Parks et al. (2014) found that the attentional process was strongly affected by contexts made by distracting stimuli. In their study using a continuous performance paradigm (Kim & Hopfinger, 2010), a distractor of either a neutral, fearful faces or a place were presented at the center of the screen while the participants detected a direction of a target appeared on the periphery. They found that when the context of the distractor was different (i.e., a place or a face), participants' attention was captured to the distractor causing longer reaction time for target detection (i.e., attentional capture), and such distracting effects remained longer only for the face distractors (i.e., attentional holding). On the other hand, such attentional holding effects were not observed when the context of the distractors was congruent (i.e., only faces).

Attentional bias to threat may also be related to the level of anxiety. Largely, the high level of anxiety induces greater attentional bias to threatening stimuli (Kim et al., 2018). Increased attentional bias can make perception of dangerous element more sensitive, in turn, it will arouse anxiety, forming a vicious circle (Power & Dalgleish, 1999). However, findings on the attention patterns associated with anxiety have been inconsistent. Some studies proposed that anxious people exhibited 'vigilance' pattern allocating faster attention to negative emotional stimuli (MacLeod et al., 1986; Mogg et al., 1997), whereas others argued 'avoidance' from negative emotional stimuli (Monk et al., 2006; Moriya & Tanno, 2011; Sagliano et al., 2015). A 'vigilance-avoidance' pattern was also reported, which indicated initial allocation of attention to negative emotional stimuli and then withdrawal (Garner et al., 2006; Mogg et al., 1987, 2000). Thus, further investigation is necessary to elucidate the attentional patterns associated with negative emotional processing.

The other factor influencing attention-emotion interaction patterns is age. Unlike young adults who normally show attentional bias to threatening and negative stimuli (Bar-Haim et al., 2007; Parks et al., 2014), older adults reveal attentional bias to positive stimuli, instead of negative information, so-called the positivity effects (Yeon & Kim, 2018). Interestingly, despite different patterns of attentional bias in young and older adults, older adults also showed mood-related attentional bias as shown in young adults (Knight & Durbin, 2015). However, children and adolescents seem to reveal dissimilar attentional bias patterns to adults. While attentional bias to threat in adults tend to be modulated by their anxiety levels, children exhibit initial attentional bias to threat-related stimulus regardless of anxiety level (Kindt et al., 1997a,b; Waters et al., 2004). In addition, Seefeldt et al. (2014) investigated the attentional holding in children with social anxiety disorder by presenting angry and neutral faces and examining their eye movements. Results showed that the children exhibited the attentional bias to angry face regardless of the level of anxiety. Further, a study with non-clinical sample of school-children (Ortega et al., 2015) reported no effects of trait-anxiety level on attentional bias to threat. Taken together, the attentional bias to negative stimuli appears differently with different ages and the levels of anxiety.

In the current study, we aimed to investigate the interaction between attention and emotion in adolescents and young adults. Developmental differences on the attentional bias to threat have been reported in research with children with adolescents (Gamble & Rapee, 2009; Roy et al., 2008), and with children and young adults (Waters et al., 2004). However, only few studies directly compared adolescents and young adults in terms of attentional bias to threat. Adolescence is not only a rapidly developing stage both cognitively and emotionally, but also a transition period from childhood to adulthood. Considering emotional states of adolescents which are more intense than those

of adults (Larson & Lampman-Petraitis, 1989), it is worth to directly compare the attentional bias to threat between adolescents and young adults.

Indeed, neurodevelopmental studies have provide a basis for studies to compare adolescents and early adulthood. It has been reported that the prefrontal cortex and amygdala, involved in attention and emotion processing respectively, develop structurally from late childhood to adolescence (Casey et al., 2000; Guyer et al., 2008; Monk et al., 2003). Monk and colleagues (2003) investigated the attention-emotion interaction in adolescents, and observed that adolescents were easily distracted by the properties of stimuli with emotional arousal, which suggested that adolescents relied more on stimulus-driven attention. In contrast, young adults tended to maintain their attention to the target, indicating use of the goal-directed attention based on matured brain function. Such findings suggest that the adolescents may have difficulty maintaining goal-directed attention when negative emotional stimuli are presented as distractors. However, no studies investigated different patterns of attentional bias, namely attentional capture and attentional holding, to threatening stimuli in adolescents. Further, it is not clear whether the anxiety level is associated with the degree to attentional bias to threat in typically developing adolescents.

For the abovementioned reasons, here we tested the relationships between the attentional bias patterns and the level of state and/or trait anxiety. The state anxiety, which is a temporary condition characterized by subjective tension (Spielberger et al., 1983), is thought to affect the evaluation of threat values at the initial stage of attention processing, whereas the trait anxiety is involved in attentional allocation at the subsequent stage (Williams et al., 1988). Most research on the relationship between attentional bias and anxiety have focused on either state anxiety (e.g., Fox et al., 2001; Mogg et al., 1997) or trait anxiety (e.g., Calvo & Avero, 2005; Rohner, 2002; Vassilopoulos, 2005; Veerapa et al., 2020) only. However, the present study examined how both the state and trait anxiety would affect attentional bias to negative emotion stimuli.

To examine attentional bias patterns (both the capture and holding effects) in adults and adolescents, we employed and modified the continuous performance task used in Parks et al. (2014). One notable modification is that we used ‘angry’ face as a negative emotion stimulus while Parks et al. (2014) used ‘fearful’ faces. Fear is closely related with fight-flight response, on the other hand, anger is considered as more cognitive and social emotional response with a sense of direct threat (Adams et al., 2003; Adolphs et al., 1999). Thus, we assumed that the attentional bias toward angry faces was more appropriate for studying social and emotional functions in developing populations.

Compared to the paradigms in previous studies on attentional bias to threat (e.g., Namaky et al., 2017, Waters et al., 2012), the current paradigm have some notable advantages. First, our paradigm allows to examine the initial attentional capture and subsequent attention holding effects simultaneously by presenting stimuli longer than previous studies (e.g., Fox et al., 2001; Vassilopoplos, 2005; Waters et al., 2012). Second, negative emotional stimuli are task-irrelevant distractors, rather than the targets, and the distractors were presented at different location from the target. This made it possible to separately measure attentional bias toward emotional distractors during the target detection processing. Most previous studies testing the attentional bias to threat presented emotional stimuli as targets or presented the target and the emotional distractors at the same location consecutively, which might be related to the reasons for inconsistent findings on attentional bias (Gerdes et al., 2008).

To summarize, the present study primarily investigated the attentional bias caused by emotional facial expressions and examined the bias patterns in adolescents and young adults. We expected that neurotypical adults would show the attentional capture effects to emotional distractors but not show attention holding ef-

fects regardless of the types of distractor. For the adolescents, we expected that they would exhibit the attentional capture for all distractors and the attention holding effects to the angry face distractors maybe due to their elevated emotion processing levels and lower cognitive control abilities. We also aimed to examine the interaction between attention and anxiety in both age groups. We predicted significant correlation between the trait anxiety and attentional capture toward angry faces in adults, while no significant correlation between any type of anxiety levels and the attentional bias in adolescents.

2. METHODS

2.1. Participants

For the young adults group, twenty college students (10 males) aged 18 to 23 years (mean age 20.85) were recruited through psychology class or via internet advertisement. After finishing the experiment, each participant received an extra credit for class or a gift certificate of five thousand won (approximately 5 dollars). For the adolescents group, Twenty teenagers were recruited via internet and advertisement flyer. Two adolescent participants were excluded from the analyses due to their performance at the continuous performance task that was lower than 3 standard deviation from the mean. Thus, the total of 18 adolescents (7 females, Mean age 14.0) were included in the final analysis. After participation, each received a gift certificate of five thousand won.

All participants had normal or corrected-to-normal vision. Participants were provided with detailed explanation about the study and written informed consent before the experiment. All procedures and informed consent were approved by the Institutional Review Board of Duksung Women's University.

2.2. Task and measures

2.2.1. Continuous performance task

The continuous performance task was run on an Intel-core i3 laptop and presented on a 13" LCD monitor. Distractor face stimuli were selected from the Korean Facial Expresssions of Emotion (KOFEE; Park et al., 2011). Sixteen images (eight angry and eight neutral faces; eight males and eight females) were selected.

At the beginning of each trial, participants fixated their gaze at the "+" at the center of the screen. After 4 seconds, a target stimulus a blue "T" appeared at the top-right corner of the screen (8.37° × 8.37°) and changed its direction every seconds. At the same time, a distractor stimulus (i.e., an angry or neutral face, 5.88° × 5.88°) abruptly appeared at the center of the screen and lasted for 4 seconds. If the target direction was horizontal or vertical (0°, 90°, 180°, 270°), participants were asked to press "1" button on the keypad. If the target direction was diagonal (45°, 135°, 225°, 315°), participants had to press "2" button. The distractor did not contain any information about the target (i.e., task-irrelevant), and participants were instructed to respond to the target as fast as possible ignoring the distractor. The interval of each onset of each distractor was either 3, 4, 5 or 6 seconds in random order throughout the trials to

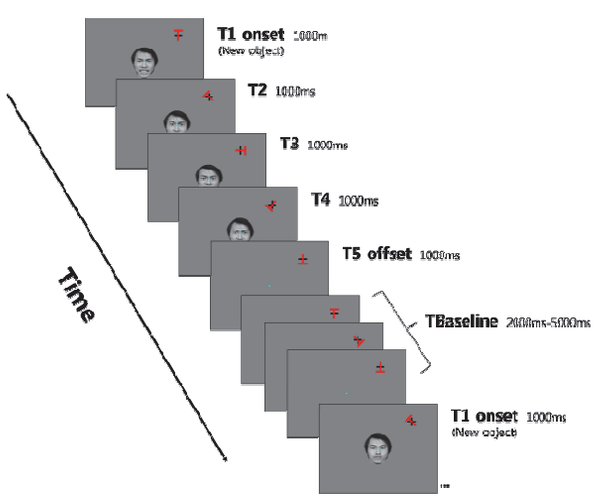

Fig. 1. Trial structure of the continuous performance task

prevent the participants from anticipating the moment of the onset of the distractor. Accuracy and reaction time (RT) data were collected from each participants. Fig. 1 shows a schematic trial structure of the task. The experiment consisted of a practice block and four blocks of main trials. Each block had 204 trials, thus total trials were 816. The practice block took 70 seconds and the main trials lasted for 16 min 20 seconds.

2.2.2. State-trait anxiety inventory (STAI-X-I,II)

The Korean version of the State-Trait Anxiety Inventory (STAI-X-I, II; Spielberger et al., 1983; Kim & Shin, 1978) was used to measure state and trait anxiety. STAI-X-I, II consists of 20 items with 4-point Likert scale, and its score ranges from 20 to 80. Cronbach's alphas of the state and trait anxiety were .91 and .92, respectively.

2.2.3. Procedures

Participants were told information on the study in detail and wrote the informed-consent. Parents or legal guardians of adolescents also signed the consent. After submitting the written consent, the participants completed the questionnaire of STAI-X-I,II. Then, the instruction on the attention task was provided. Next, the participants performed the practice trials and the main trials of the attention task. Distance between the participants and the screen maintained 50 cm during the task.

3. RESULTS

3.1. State and trait anxiety

Mean STAI-X-I (state anxiety), STAI-X-II (trait anxiety) scores were 40.05 (SD 11.14) and 41.75 (SD 11.34) respectively in twenty young adult participants. Given that the average scores for the state and trait anxiety were 42.5 (SD 9.99) and 44.53 (SD 9.50) in the original study (Kim & Shin, 1978), such scores in our adult participants indicate that they have the typical level of state and trait anxiety.

In adolescents group, mean state and trait anxiety scores were 35.74 (SD 8.00) and 39.06 (SD 7.77), respectively. Given that the average scores for the state and trait anxiety were 45.89 (SD 10.93) and 46.24 (SD 10.05) in adolescents in the original study (Kim & Shin, 1978), the adolescents in the current study also had the typical level of state and trait anxiety.

3.2. Attentional bias by the distractor type and time

Table 1 shows the results from the continuous performance task. In Table 1, T1 (Time 1) indicates the target which appeared with the onset of a distractor (angry or neutral faces). T2 means the target presented 1 second after the onset of the distractor. Likewise, T3 and T4 indicate the target appeared 2 and 3 seconds after the distractor onset respectively. T baseline is the targets

Table 1. Response time depending on the distractor type and time

	Adults		Adolescents	
Time	Angry face	Neutral face	Angry face	Neutral face
1	535.10(52.92)	536.00(55.40)	605.88(58.10)	600.77(55.96)
2	513.39(44.36)	514.56(47.43)	581.25(47.97)	589.44(50.51)
3	512.64(44.39)	507.64(50.71)	578.30(46.71)	581.54(50.54)
4	504.57(48.44)	515.98(50.52)	576.66(48.67)	575.89(51.90)
Baseline	505.67(44.48)	515.62(49.19)	576.52(44.76)	586.83(51.15)

Note. Means (standard deviations)

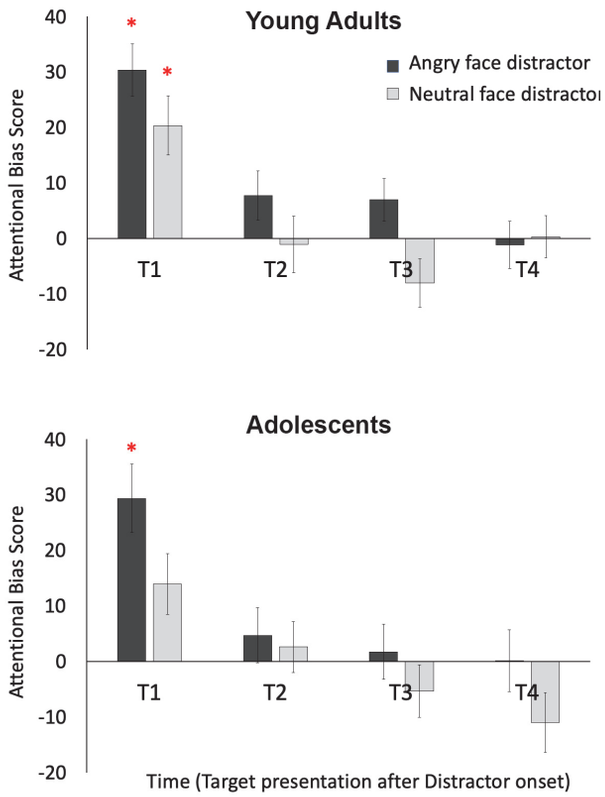

Fig. 2. Attentional bias patterns in adults (top) and in adolescents (bottom)

during the distractor absent (after the offset of the distractor), where no attentional bias is observed (Park et al., 2014). RTs to detect the target direction were recorded in each time condition (T1, T2, T3, T4, T baseline) × distractor types (angry and neutral face), which is summarized in Table 1.

For the young adults group data, A 2 (Distractor type; angry, neutral) × 5 (Time conditions: T1, T2, T3, T4, T baseline) repeated measures of ANOVA was conducted (Fig. 2 top). In the results, a main effect of Distractor type was not significant, F (1,19) = 1.95, p = .18, but a main effect of Time was significant, F(2.77, 52.61) = 16.62, p < .001. There was a tendency of significant interaction between Time and Distractor, but did not reach to the significant level F(4, 76) = 2.26, p = .07. For the main effect of Time, we conducted post-hoc paired t-tests between each time and baseline in each distractor types. The results revealed that RTs for T1 for both the angry and neutral face distractors were significantly longer than RTs for T baseline [angry face; t(19) = 6.41, p < .01 neutral face; t(19) = 3.83, p < .01] (Fig. 2 top). However, there was no significant difference in the other time conditions regardless of distractor types. These results indicate the attention capture effects, but not the holding effects, due to the facial distractors in the early attention process in young adults.

A 2 × 5 repeated measures of ANOVA was also conducted with the adolescents group data. The results showed a significant main effect of time (F(4, 68) = 13.534, p < .001), but neither a main effect of distractor type nor the interaction between the two factors was significant (F(1, 17) = .56, p = .47, and F(4, 68) = 1.28, p = .29, respectively. Fig. 2 bottom). Then, paired t-tests were conducted to examine whether the attention bias in each time condition was significant relative to baseline. The results showed that RTs in the T1 condition for angry face was significantly longer than T baseline, t(17) = 4.77, p < .01 (Fig. 2). This result indicates that adolescents show attentional capture effects only for the angry face distractor, unlike young adults who showed attentional capture effects for both angry and neutral faces. There was no significant differences in the other time conditions for all distractor types.

3.3. Correlation between the attentional bias and anxiety levels

To measure the attentional bias caused by the distractors relative to baseline, the attentional bias score was calculated as below.

Attentional bias score = RTs in each time conditions (T1, T2, T3, T4) - RTs in T baseline

Then, a series of correlation analyses between the attentional bias scores and anxiety levels were conducted to test whether the attentional bias to faces was related to the levels of anxiety. In the adults group, significant

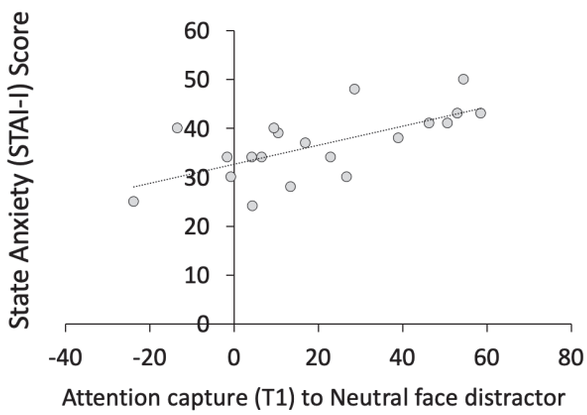

Fig. 3. Correlation between the attentional capture by neutral faces and STAI-X-I scores in adults

positive correlation between the attentional capture score and the level of state anxiety was observed when the distractor was neutral face, r = .66, p < .01 (Fig. 3), indicating that the higher state anxiety level, the greater attentional capture to the neutral face distractor. When the distractor was angry face, no significant correlation was found, although the correlation between the attention capture scores and the level of trait anxiety was close to significance level, r=.40, p=.08.

In contrast, significant correlations between the attentional capture effects (at T1) and the levels of anxiety (i.e., state, trait) were not found in any distractor types (all ps > .05) in adolescents.

3.4. Comparison of data from the two groups

Finally, to further test effects of age on attentional bias to threat, we conducted additional 2 (Age; adults, adolescents) × 2 (Distractor type; angry, neutral) × 5 (Time conditions: T1, T2, T3, T4, T baseline) repeated measures of ANOVA using data from the two groups. The results showed a significant main effect of Time, F(3.07, 110.38) = 29.64, p < .001. Further, a significant effects of Age was found, F(1, 36) = 20.50, p < .001, indicating adults were faster to respond to the targets than adolescents in all conditions (Table 1). No other effects were signicant (all ps > .05)

4. DISCUSSION

The present study examined whether the attentional bias would be caused by an emotional face distractor as in Parks et al. (2014), and investigated how these attentional bias would appear in young adults and adolescents. We also examined whether the anxiety level would be related to the attentional bias in the two age groups.

In the young adults, a significant attentional capture effect was observed when the target was presented with the distractor at the same time (i.e., T1) for both the angry and neutral face distractors. However, the attentional holding effect was not observed in any conditions. These results are consistent with those in Parks et al. (2014). Specifically, Parks et al. (2014) demonstrated that negative facial expression did not hold attention when the distractor context was the same. It is worth to note that our results replicated the previous study in spite of different negative emotion stimuli (i.e., using angry faces as distractors). Both anger and fear are negative emotions, but there is difference between them in that ‘fear’ is the signal from potentially dangerous cues in the environment, whereas ‘anger’ signals more direct threat (Adams et al., 2003; Adolphs et al., 1999; Whalen et al., 2001). Therefore, our findings suggest that attentional bias toward negative facial expression may be general, not only linked with a specific emotion.

In the adolescents group, however, the attentional capture effect was observed only for the angry face distractors. This result was different from our hypothesis in which we expected that there would be attentional capture effects for both the angry and neutral faces. It is possible that adolescents may be relatively more sensitive to negative emotion of anger compared to adults. It is known that adolescents exhibit higher sensitivity to salient environmental cues than adults (Somervile et al., 2010), and anger should be a highly salient cue in terms of its signaling direct threat. Moreover, angry ex-

pression of others has a role of preventing and stopping socially inappropriate or rule-breaking behaviors (Averill, 1983), thus sensitivity to anger may have greater importance for social and emotional development in adolescence. Neurodevelopmental studies have also provided supportive evidence. For example, adolescents exhibited greater amygdala activation than adults when they viewed a negative facial expressions (Guyer et al., 2008), and greater activation in the anterior cingulate cortex even when conducting non-emotional tasks with negative emotional face stimuli (Monk et al., 2003). Thus, it is possible that the selective attentional bias to angry faces in adolescents was due to their relatively greater sensitivity to negative emotional cues.

In contrast, attentional holding, a prolonged distraction by faces, was not observed either the angry or the neutral faces. This result indicates that the attention was initially captured by the distractor, but after one second, participants could pay full attention to the target without holding their attention to the distractor, or could use 'goal-directed attention.' Such results suggest that adolescents aged 13 to 16 years can use their goal-directed attention similar to young adults.

Turning to the relationships between attentional bias and the level of anxiety, there was a tendency of positive correlation between attentional capture to angry face and trait anxiety levels in adults. This could be consistent with previous findings that reported elevated attentional vigilance to angry face in individuals with anxiety disorders (e.g. MacLeod et al., 1986; Mogg et al., 1997), however, further interpretation is limited as the correlation did not reach to the significant level. More importantly, a significant positive correlation was found between attention bias toward neutral faces and the levels of state anxiety. Previoulsy, Somervile et al. (2004) and Cooney et al. (2006) reported a positive correlation between self-reported state anxiety and the amygdala response to neutral faces. The researchers argued that neutral faces had emotional ambiguity, thus were affected by the level of state anxiety during processing (Somervile et al., 2004). In the current study, the degree of attentional capture by the neutral faces were associated with higher levels of state anxiety in adults, and this results could be due to the higher needs to evaluate emotions in the ambiguous neutral faces.

In contrast to the results in adult participants, significant correlation between attentional capture and state or trait anxiety levels was not observed in adolescents. Previous studies with typically developing children and early adolescents aged 7~9 (Kindt et al., 1997a,b), 9~12 (Waters et al, 2004), and 8~13 (Ortega et al., 2015) also reported attentional bias towards threatening stimuli, the researchers did not report significant relationships between the anxiety levels and the attentional bias. In this context, our result extends the previous findings to adolescent aged 13~16 years. Taken together with previous findings, the development of attention-emotion interaction in terms of attentional bias seems to be incomplete upto the age of 13-16, suggesting that the degree of attentional bias may be more affected by the level of attentional control in children and adolescents rather than the level of anxiety. Further longitudinal research merits to elucidate the developmental trajectory of interaction between attentional control and the level of anxiety in youth.

To our knowledge, this is the first study investigating the developmental tendency of attentional bias to negative facial emotion by comparing adults with adolescents using the attentional task measuring both early attentional capture and late attentional holding. Most previous studies have focused on adult population only, or have compared between young and older adults. In addition, we measured both trait and state anxiety levels to examine the relationships between attention and anxiety in adults and adolescents.

Further, our findings of the correlation between attentional bias and anxiety has some clinical implications for improving intervention programs for people with

high anxiety or social anxiety disorders, such as attentional bias modification training programs. In general, a principle of the attentional bias modification contains procedures that suppress selective attentional bias for negative faces and make individuals pay attention to neutral faces (Amir et al., 2008; Enock et al., 2014). However, here we demonstrated that the attentional capture toward the neutral faces was significantly related to the levels of state anxiety in neurotypical adults. Such results suggest that the neutral faces, likely due to its emotional ambiguity, might not be the optimal items to reduce anxiety in the training program for people with high anxiety. Thus, to develop programs to reduce the level of anxiety, it would be necessary to consider using other types of neutral stimuli or positive emotional faces rather than neutral faces.

There are a few limitations in our study. First, the sample size was relatively small, and the range of age in our adult group was narrow. In the follow-up study, more participants with wide range of age should be recruited. Second, the eye-tracker was not used during our attention task. Although we emphasized participants to fixate the center of the screen while attending to the target in the periphery (i.e., covert attention), there is still possibility that participants moved their gaze to the target location during the trials. However, as significant attentional capture effects were found both adults and adolescents, we do not believe that such uninhibited eye movements have affected our results seriously. Nevertheless, the use of eye-tracking methods will be helpful to ensure the process of covert attention in the future study.

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