Facilitation of gaze-triggered attention orienting by a fearful expression and its relationship to anxiety

Shota Uono[1,2], Wataru Sato[3], Chikashi Michimata[4], Sakiko Yoshikawa[5], and Motomi Toichi[6]

[1]Japan Society for the Promotion of Science, 8 Ichiban-cho, Chiyoda-ku, Tokyo 102-8472, Japan

[2]Department of Cognitive Psychology in Education, Faculty of Education, Kyoto University, Yoshida-honmachi, Sakyo-ku, Kyoto 606-8501, Japan

[3]Department of Comparative Study of Cognitive Development (Funded by Benesse Corporation), Primate Research Institute, Kyoto University, 41-2 Kanrin, Inuyama, Aichi 484-8506, Japan

[4]Department of Psychology, Faculty of Human Science, Sophia University, 7-1 Kioi-cho, Chiyada-ku, Tokyo 102-8554, Japan

[5]Kokoro Research Center, Kyoto University, 46 Shimoadachi-cho, Sakyo-ku, Kyoto 606-8501, Japan

[6]Faculty of Human Health Science, Graduate School of Medicine, Kyoto University, 53 Shogoin Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan

Abstract

Previous studies have suggested that emotional facial expression has a facilitative effect on attention orienting by gaze cues depending on the anxiety level; however, evidence has been inconclusive. We investigated this issue by presenting fearful and neutral faces with straight, right, and left gazes as cues. Forty-six healthy participants were asked to detect a peripheral target following the cue. After the experiments, their state and trait anxiety levels were evaluated. The reaction time under the valid condition was shorter for fearful than for neutral faces only in the high state anxiety group. Regression analyses showed a positive relationship between the effect of attention orienting by fearful gaze and state anxiety. These results indicate that fearful gaze facilitates attention orienting compared to neutral gaze as participants' state anxiety levels increase.

Keywords: attention orienting; facial expressions of fear; gaze; state anxiety

1. Introduction

The gaze direction of other individuals provides crucial information. Through the evolutionary process, the ability to rapidly orient attention to another's gaze direction would have helped humans detect biologically significant stimuli, such as predators and food, and thus would have conferred a survival advantage. Recent experimental studies have shown that rhesus macaques (Deaner & Platt, 2003) and 3-month-old human infants (Hood, Willen, & Driver, 1998) were faster to make a saccade to a gaze-cued target than to a non-cued target.

Studies of human adults have also shown that another's gaze direction triggered covert attention orienting (Friesen & Kingstone, 1998; Driver et al., 1999; Langtone & Bruce, 1999). These studies investigated the nature of attention orienting by gaze cues, using modified versions of Posner's (1980) cueing paradigm. For example, Friesen and Kingstone (1998) presented a schematic face with right, left, or straight gaze in the central visual field; subsequently, a target appeared at the right or left side of the face. Participants were instructed that gaze direction was non-predictive of where the target would appear. Nonetheless, their reaction time (RT) was shorter for detecting a target at a gaze-cued location (valid condition) than at a gaze-uncued location (invalid condition). The results suggest another's gaze direction triggers reflexive attention orienting.

These studies used neutral facial expressions as cue stimuli, but

emotional expressions may enhance attention orienting by gaze cue. Emotional facial expressions inform others of the adaptive value of attending to objects. Specifically, fearful expressions signal to others that attended objects are threatening and should be avoided (Adolphs, Russell, & Tranel, 1999; Whalen et al., 2001; Blair, 2003). If facial expressions of emotions such as fear more rapidly trigger attention orienting by gaze cues, this response could be considered adaptive by increasing the probability of avoiding a threatening stimuli.

Hietanen and Leppänen (2003) tested this idea, but the results were not supportive. The study presented still images of photographed and schematic faces as cue stimuli; the stimuli included neutral and emotional (happy, angry, and fearful) faces with right, left, or straight gaze. The results indicate that emotional faces did not enhance attention orienting by gaze cues compared to neutral faces and other emotional faces. In experiment 5 of their study, emotional faces with right or left gaze were presented following emotional faces with straight gaze. This presentation method allows emotional expressions to be sufficiently processed before presentation of gaze direction information. Nevertheless, the results showed that emotional faces do not enhance attention orienting by gaze cue compared with the other emotional face. The series of the experiments consistently produced the same results irrespective of a wide range of stimulus onset asynchrony (SOA) between the gaze cue and target.

In contrast, three other studies (Mathews, Fox, Yiend, & Calder, 2003; Holmes, Richards, & Greene, 2006; Fox, Mathews, Calder, &

Yiend, 2007) reported that emotional facial expressions had facilitative effects on attention orienting by gaze cues when the factor of participants' state or trait anxiety was included. According to Spielberger, Gorsuch, & Lushene (1970), state anxiety is a transient emotional state characterized by subjective feelings of tension and apprehension, and heightened autonomic nervous system activity. Trait anxiety is relatively stable individual differences in anxiety proneness. In their experiments, Mathews et al. (2003) moved the gaze direction from the central to the left or right sides after the presentation of neutral or fearful faces for 900 ms. Although interactions among gaze cue, facial expression, and trait anxiety only reached marginal significance, follow-up analyses showed that the gaze cueing effect (invalid–valid) of a fearful face was larger in the high trait anxiety group than in the low trait anxiety group. The RT difference between fearful and neutral faces under the valid condition was also larger in the high trait anxiety group than in the low trait anxiety group. A follow-up study by Fox et al. (2007) obtained clear evidence for the facilitated gaze cueing effect for fearful facial expressions, and its relation to the level of anxiety. They used a similar experimental paradigm with Mathews et al. (2003). The results showed that gaze cueing effect for fearful faces was significantly larger than for angry, happy, and neutral faces in participants with high trait anxiety, and gaze cueing effect for fearful faces was positively correlated with participant's state and trait anxiety level. Holmes et al. (2006) presented photographs of angry and neutral facial expressions with right, left, or straight gaze as cue stimuli. Although the result

showed no significant interactions among gaze cue, facial expression, and state anxiety, they conducted an exploratory partial analysis. The results showed that the gaze cueing effect for angry faces was larger than that for neutral faces only in the high state anxiety group. These previous results suggest that a larger gaze cueing effect could be induced by emotional faces rather than neutral faces in participants with high anxiety. However, problems remain with this suggestion.

First, it could be problematic for some studies (Mathews et al., 2003; Fox et al., 2007) that fearful expressions were presented for as long as 900 ms before gaze shift. This preceding presentation of fearful faces made it unclear whether the results could be accounted by the priming effect of preceding emotional facial expression on subsequent gaze-triggered attention orienting by the rapid interaction between emotional facial expression and gaze direction. The simultaneous presentations of information of gaze direction and facial expression would be more appropriate to investigate this issue. Although some studies tested the simultaneous presentations (Hietanen & Leppänen, 2003; Holmes et al., 2006), they did not report significant results.

Second, previous studies (Mathews et al., 2003; Holmes et al., 2006; Fox et al., 2007) reported inconsistent results regarding the effect of participants' anxiety levels. While Mathews et al. (2003) and Fox et al. (2007) showed an evident gaze cueing effect for emotional faces in high *trait* anxiety groups, Holmes et al. (2006) showed this effect in the high *state* anxiety group. In a footnote, Mathews et al. (2003) reported that they reanalyzed the data after excluding participants who had high

trait anxiety but below-median state anxiety and who had low trait anxiety but above-median state anxiety. By partially excluding the influence of state anxiety, the results showed significant interactions among emotional expression, validity, and trait anxiety. Therefore, it is unclear whether this result can be accounted for by the modulation effect of only trait anxiety. These data suggest that state anxiety also modulated attention orienting by gaze cues in Mathews et al.'s (2003) experiment.

In the present study, we investigated the gaze cueing effect of fearful and neutral facial expressions, and its relationship with the level of anxiety. We presented fearful and neutral faces with left, right, or straight gaze as cue stimuli in the cueing paradigm. Participants were asked to detect a peripheral target following the cue. After the experiments, we measured the state and trait anxiety levels of the participants. Based on the results of previous studies (Mathews et al., 2003; Holmes et al., 2006; Fox et al., 2007), we predicted that gaze cueing effect for fearful faces would be larger than neutral faces in high state/trait anxiety participants and be positively correlated with state/trait anxiety level. We also predicted that gaze cues in fearful faces would more rapidly orient attention than gaze cues in neutral faces in high state/trait anxiety participants.

2. Methods

2.1. Participants

Forty-six healthy volunteers (28 females and 18 males; mean ± *SD* age, 21.8 ± 1.2 years) participated in this experiment. All of the participants had normal or corrected-to-normal visual acuity. Although two additional participants were tested, their data were not analyzed because they did not fill out questionnaires.

2.2. Experimental design

The experiment was constructed as a within-participants two-factorial design, with facial expression (fearful and neutral) and validity (valid, invalid, and non-cued) as the factors.

2.3. Stimuli

We selected the cue stimuli from Ekman and Friesen (1976). Four neutral and fearful face photographs were selected and manipulated. The selected two fearful faces were of the same identity as the selected neutral face. We cropped all the photographs in an ellipse shape, 4.2° wide and 5.7° high, to exclude the hair and background. To manipulate gaze direction, the irises and pupils of the eyes were cut from all the photographs and pasted to fit in the right or left corners of the eyes

using Photoshop 5.0 (Adobe). We used a total of 24 photographs, facial expression (fearful and neutral) x gaze direction (right, left, and straight) x person (2 males and 2 females), as cue stimuli. Examples of stimuli are shown in Fig. 1a.

A letter T (0.8° wide and 0.8° high), presented 5° to the left or right side of the center of the screen, was used as a target stimulus.

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Insert Fig. 1 about here

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2.4. Apparatus

Stimulus presentation and data acquisition were controlled by PsychoToolbox (Brainard, 1997) on the MATLAB platform (Cybernet System) implemented on a PowerMac G3 (Apple). Stimuli were presented on a 15-inch CRT monitor (Sony; screen resolution 1024 x 768 pixels; refresh rate 85 Hz). The distance between the monitor and participants was controlled at approximately 90 cm, using a headrest.

2.5. Procedure

In each trial (Fig. 1b), a fixation cross was first presented at the center of the screen for 680 ms. Subsequently, a neutral or fearful face photograph with right, left, or straight gaze as the cue stimulus was

presented at the center of the screen. Then, after 500 ms, a target letter T appeared to the left or right side of the cue stimulus. Participants were asked to press a button as quickly as possible when a target appeared but not to respond if a target did not appear. The duration from target appearance to button response was measured in each trial. A target and cue remained until the response. When 2000 ms elapsed with no response, the next trial started. Participants were instructed that cues were non-predictive of target location and were asked to fixate on the center of the screen in each trial.

The experiment consisted of 8 blocks of 30 trials, including 48 catch trials. Each condition consisted of 32 trials. Trials were presented in pseudorandom order, and block order was counterbalanced across participants. Participants could rest freely between blocks. Thirty practice trials preceded the experimental trials.

After completion of this task, participants filled out the college student version of the Japanese version (Shimizu & Imahide, 1981) of the State–Trait Anxiety Inventory (Spielberger et al., 1970).

2.6. Data analysis

The data were analyzed using SPSS 10.0J (SPSS Japan). Incorrect responses and <100-ms responses were excluded from the RT analysis. The median RT under each condition was calculated for each participant. To satisfy normality assumptions for the subsequent analyses, the data were subjected to log transformation.

To test our predictions, the log-transformed RT was analyzed with a general linear model with qualitative factors of expression (fear, neutral) and gaze cue (congruent, incongruent, front), and quantitative factors of trait anxiety and state anxiety, with the participant as the block factor. The analysis corresponded to a repeated-measures analysis of covariance (ANCOVA) with the general linear model approach (cf., Tabachnick & Fidell, 2001). For the analysis, we confirmed that the assumption of sphericity was not violated ($p > .1$). The trait and state anxiety showed a moderate positive correlation ($r = .41$, $p < .01$), but apparently not high enough to induce multicollinearity (cf., Tabachnick & Fidell, 2001). Hence, we included both of the variables in the analysis. For significant interactions of expression x validity x anxiety (either of trait or state), two types of follow-up analyses were conducted.

First, the simple effects of facial expression under each gaze cue condition (valid, invalid, and non-cued) in both high and low anxiety groups were analyzed using Scheffe's multiple comparison tests. Second, the simple interactions of validity x anxiety were analyzed for each of the facial expression conditions (fear, neutral). To implement these analyses, regression analyses were conducted with the RT difference for the validity conditions (invalid versus valid) as the dependent variable and the anxiety score as the independent variable.

3. Results

The ANCOVA revealed an interaction of facial expression x

validity x state anxiety ($F(2,86) = 3.30$, $p < .05$). A trend toward an interaction of facial expression x validity ($F(2,86) = 2.93$, $p < .1$) was observed, with no other significant interactions or main effects ($ps > .1$). For analysis of three-way interaction, we conducted two follow-up analyses, described below.

3.1. The effect of facial expression on gaze-triggered attention orienting in high and low state anxiety groups

To investigate the prediction that gaze cues in fearful faces would orient attention more rapidly than those in neutral faces in high anxiety participants, participants were divided by their state anxiety score into two groups. The 21 participants (7 males and 14 females) whose state anxiety scores were above 37 points ($M \pm SD = 40.33 \pm 2.99$) were classified as the high state anxiety group. The 22 participants (10 males and 12 females) whose state anxiety scores were below 35 points ($M \pm SD = 31.41 \pm 3.14$) were classified as the low state anxiety group. Three participants had state anxiety scores that equaled the median (36 points) of all participants' scores; the data for these three participants were excluded from the analysis. A significant difference was seen in the state anxiety scores between the high and low state anxiety groups ($t(41) = 9.00$, $p < .001$). The primary focus of the analyses was the simple effect of facial expression under each condition of validity (valid, invalid, and direct) in each state anxiety group.

In the high state anxiety group (left panel in Fig. 2), the analysis

revealed a significant simple effect of facial expression under the valid condition ($F(1,20) = 10.99$, $p < .05$), indicating that the RT under the fearful face condition was shorter than under the neutral face condition. No significant simple effects were observed under the other two conditions ($ps > .1$).

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Insert Fig. 2 about here

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In the low state anxiety group (right panel in Fig. 2), the analysis revealed a significant simple effect of facial expression under the invalid condition ($F(1,20) = 8.50$, $p < .05$), indicating that the RT under the fearful face condition was shorter than under the neutral face condition. No significant simple effects were observed under the other two conditions ($ps > .1$).

3.2. Relationship between state anxiety and the gaze cueing effect in fearful and neutral expressions

To investigate the predicted positive relationship between the gaze cueing effect in fearful faces and the level of state anxiety under each of the facial expression conditions, regression analyses were conducted with the RT difference of the validity conditions (invalid versus valid) as the dependent variable and the anxiety score as the

independent variable. Under the fearful face condition (left panel in Fig. 3), the analysis showed a significant positive linear relationship between the RT difference and state anxiety score ($F(1,44) = 4.85$, $p < .05$).

Under the neutral face condition (right panel in Fig. 3), no significant linear relationship was observed between the RT difference and state anxiety score ($p > .1$).

4. Discussion

In our study, gaze cueing effect of fearful faces was larger than neutral faces in high state anxiety participants; the gaze cueing effect of fearful faces was positively related with participant's state anxiety level. There was only a non-significance trend ($p < .1$) towards an interaction between facial expressions and validity. This result agrees with the result found by Hietanen and Leppänen (2003), who simultaneously presented gaze direction and facial expression information as in the present study and reported null results for the effect of facial expressions on gaze cueing. Our results were also consistent with the results of Mathews et al. (2003), Holmes et al. (2006), and Fox et al. (2007), which showed that the gaze cueing effect of emotional faces was larger than that for neutral facial expressions when the factor of participants' anxiety level was included.

The results of our study differed in some ways from previous findings. First, although Mathews et al. (2003) and Fox et al. (2007) showed that trait anxiety mediated the effect of emotional expressions on

gaze cueing, we found that state anxiety had this effect. Our results are based on a statistical model including both state and trait anxiety and show a significant effect only for state anxiety, suggesting that participants' trait anxiety levels were not related to the gaze cueing effect by fearful faces when the state anxiety level was statistically controlled. Regarding this issue, Mathews et al. (2003) reanalyzed their data after excluding participants who had high trait scores but below-median state scores or who had low trait scores but above-median state scores and found a more powerful influence of facial expressions on the gaze cueing effect. These data suggest that not only trait but also state anxiety affected emotional gaze cueing in their study. Trait anxiety was also positively correlated with the state anxiety level in our data, as in the study by Holmes et al. (2006). The data suggest that people with a high trait anxiety level tend to have high state anxiety while participating in a gaze cueing paradigm with emotional faces. Together with these data, we speculate that Mathews et al.'s (2003) result showing the modulation effect of trait anxiety on attention orienting by fearful gaze could be explained by the modulation effect of state anxiety.

Second, compared to Holmes et al.'s (2006) findings, our results revealed a clearer effect of state anxiety on attention orienting by emotional gaze. The difference in results may reflect differences in the stimulus facial expressions. Whereas Holmes et al. (2006) used angry facial expressions, we used fearful facial expressions. While angry faces *per se* could be a source of the threat, fearful faces could signal to others that attended objects are threatening and should be avoided (Adolphs et

al., 1999; Whalen et al., 2001; Blair, 2003). These findings suggest that the facilitative effect for attention orienting by averted gaze could be more evident for fearful expressions than for angry expressions.

Our results showed that participants with high state anxiety more rapidly orient attention to the location cued by fearful gaze than neutral gaze and participants with low state anxiety disengaged their attention more effectively from the location cued by fearful gaze than neutral gaze. These findings could be reasonable when considering the adaptive functions of the emotional gaze and state anxiety. Fearful expressions signal to others that attended objects are threatening and should be avoided (Adolphs et al., 1999; Whalen et al., 2001; Blair, 2003). If people are in an environment in which a threat was predicted, more rapid attention orienting to the gaze-cued location would be an adaptive behavior. However, if they are in a safe environment and processed other information without being excessively influenced by fearful gaze, this also would be adaptive. Humans may be triggered to take collective adaptive behaviors mediated by others' gazes and expressions, only when they feel an appropriate degree of anxiety regarding the environment or others' expressions.

We speculate that a plausible neural substrate for the facilitated attention orienting by fearful gaze may involve the amygdala. Several neuropsychological and neuroimaging studies consistently indicated that the amygdala is involved in the processing of fearful expressions (e.g., Adolphs, Tranel, Damasio, & Damasio, 1994; Whalen et al., 2001). Neuropsychological studies revealed that the amygdala is involved in

gaze-triggered attentional shift (Akiyama et al., 2007; Okada et al. 2008). Neuroimaging studies reported that the amygdala activity shows the interaction between emotional expression and gaze direction (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Sato, Yoshikawa, Kochiyama, & Matsumura, 2004). Furthermore, consistent with our results, a neuroimaging study reported that the amygdala activity for fearful expressions correlates positively with the state anxiety level (Bishop, Jenkins, & Lawrence, 2007). These data suggest that the amygdala plays a crucial role for facilitative effect of fearful gaze on attention orienting mediated by state anxiety.

Whether the modulation effect of state anxiety on attention orienting by emotional gaze we found could be an innate function or one acquired through development poses an intriguing question. Previous studies have reported that newborns have an innate sensitivity to gaze and facial movement (Meltzoff & Moore, 1977; Farroni, Massaccesi, Pividori, & Johnson, 2004). Therefore, if enhanced attention orienting by emotional gaze in a novel (anxious) situation creates a shared emotional state to attended objects between infants and caregivers and facilitates the associated induced emotional state to the attended object, this modulation effect may influence the development of our social cognitive function such as empathy and facilitate learning the emotional value of objects. This question should be investigated further.

In summary, we found that attention orienting by gaze cues was more evident for fearful than for neutral faces only in the high state anxiety group. We also found a positive relationship between the effect

of attention orienting by fearful gaze and state anxiety. These results indicate that fearful gaze facilitates attention orienting compared to neutral gaze as participants' state anxiety increases.

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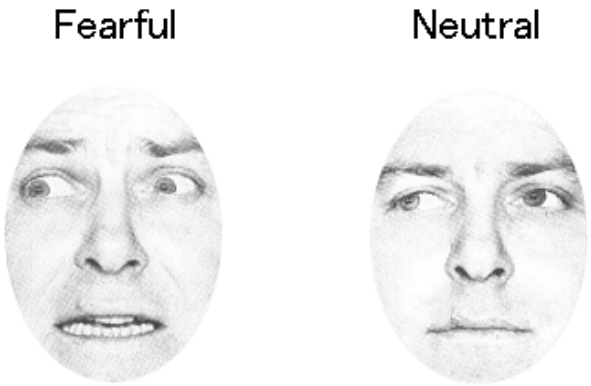
Figure Legends

Fig. 1. (a) Examples of cue stimuli. (b) The sequence of the stimulus presentation.

Fig. 2. Reaction time to detect peripherally presented targets (in milliseconds), divided into high and low state anxiety groups, for each facial expression and validity. Error bars indicate the standard error for each condition.

Fig. 3. The relationship between the gaze cueing effect of each facial expression and the state anxiety level. The vertical axis indicates the difference between the log-transformed reaction time under the valid and invalid conditions for each facial expression. Positive scores represent faster target detection under the valid versus invalid condition.

a)



b)

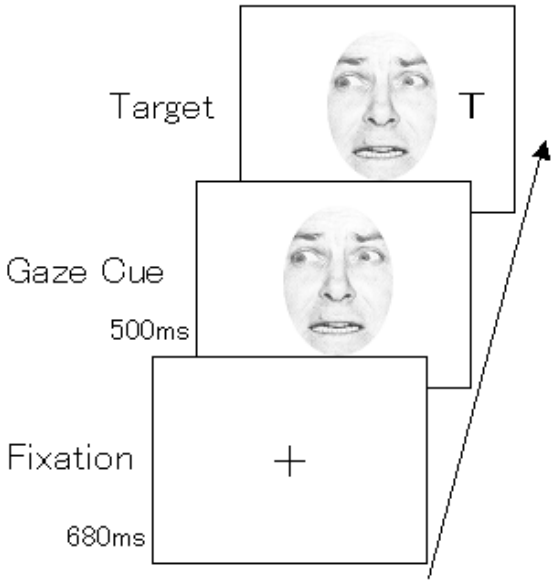


Fig. 1

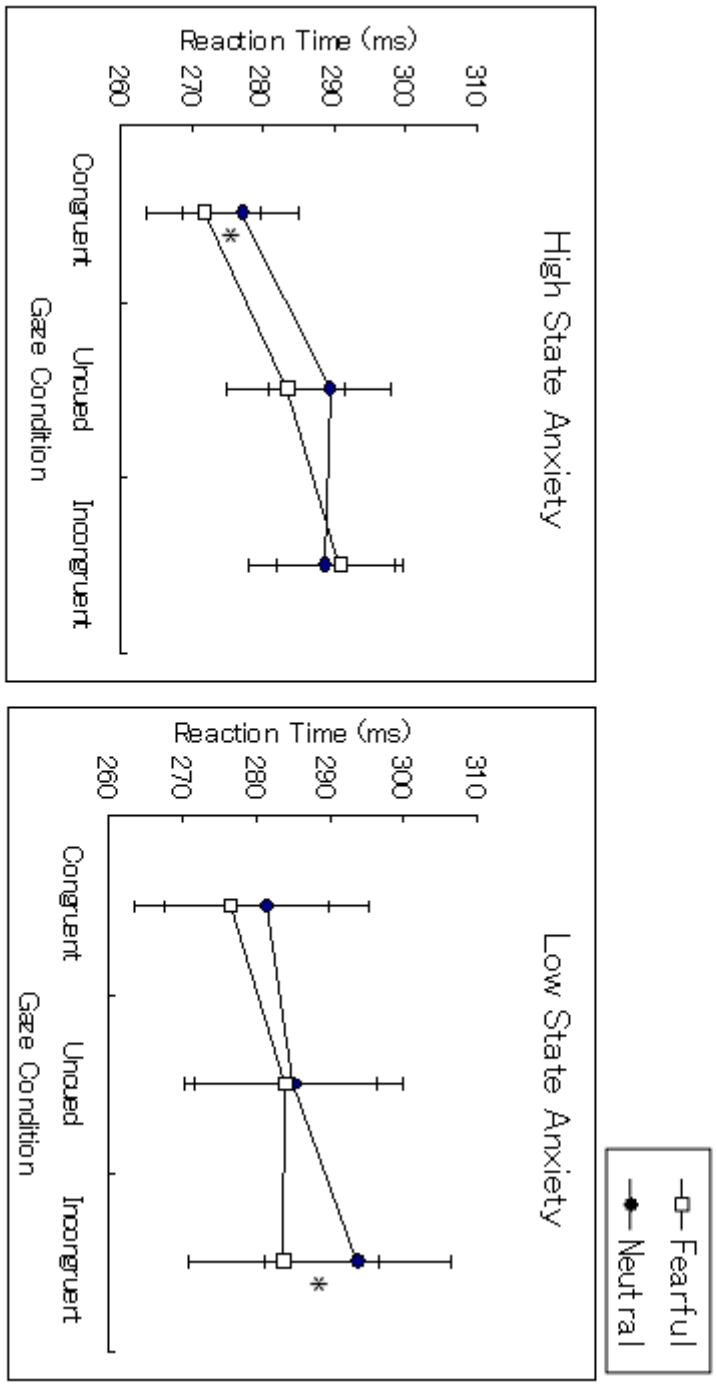

High State Anxiety
Low State Anxiety
Reaction Time (ms)
260
270
280
290
300
310
Congruent
Uncued
Incongruent
Gaze Condition
*
*
Fearful
Neutral

Fig. 2

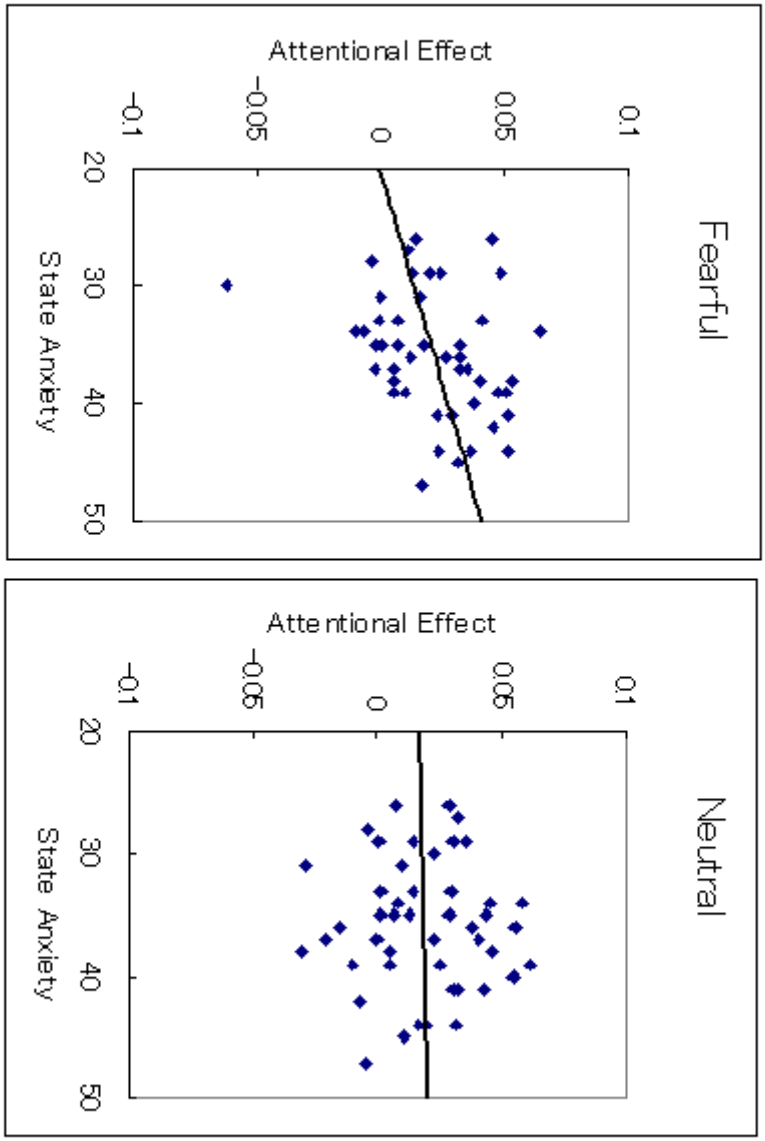

Fearful
Attentional Effect
0.1
0.05
0
−0.05
−0.1
20
30
40
50
State Anxiety
Neutral
Attentional Effect
0.1
0.05
0
−0.05
−0.1
20
30
40
50
State Anxiety

Fig. 3