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Metacognitive Monitoring of Attentional Bias Toward Threat in Anxiety

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Are anxious individuals aware that their attention is excessively captured by threat-related stimuli? If so, how accurate is this awareness? Accurate attentional monitoring is crucial for effective attentional control, as it enables individuals to recognize whether and to what extent attentional control is necessary. The present study investigates how accurately individuals (recruited in 2023–2024) monitor their attentional bias toward an angry face and whether this ability is associated with anxiety levels. Adopting a novel approach that involves average facial expression and attentional allocation judgments, we demonstrate that individuals can monitor their attentional bias toward an angry face. However, anxious individuals tend to underestimate their greater attentional bias, despite having an intact ability to monitor trial-by-trial variations in attentional bias; this may explain why they exhibit impaired attentional control. This study provides a novel theoretical framework that incorporates attentional monitoring processes to more comprehensively understand the relationship between attention and anxiety.

Keywords: anxiety, attention, attentional bias, attentional monitoring, metacognition

Supplemental materials: https://doi.org/10.1037/emo0001544.supp

Threat-related stimuli, such as an angry face or feared animals, automatically capture our attention (Carretié, 2014; Phelps et al., 2006). Attentional bias toward threat appears to be an adaptive mechanism for survival, enabling quick judgment and response to potential danger. However, excessive attentional bias that is difficult to control may pose a threat to one's well-being. Specifically, individuals with high levels of anxiety tend to exhibit an excessive attentional bias toward threat, leading to a vicious circle that further heightens anxiety levels (Bar-Haim et al., 2007; Cisler & Koster, 2010; Hur et al., 2019; Mathews et al., 1997; Mogg & Bradley, 2016; Valadez et al., 2022).

Attentional control, the ability to inhibit biased attention toward threat-related stimuli and shift attention away from them, has been extensively studied as a crucial mechanism for breaking the vicious circle of anxiety (Derryberry & Reed, 2002; Taylor et al., 2016; White et al., 2009). For example, Derryberry and Reed (2002) demonstrated a close relationship between self-reported attentional control and the ability to shift attention away from threatening locations. In particular, anxious individuals with good attentional control can disengage their attention from threatening locations. This suggests that anxious individuals may utilize attentional control to mitigate the impact of maladaptive attentional bias toward threat.

However, these findings raise the question: How can individuals control their attentional bias even without external feedback or interventions? One explanation is that individuals have introspective awareness of their attentional bias toward threat. This metacognitive monitoring of attentional bias may enable them to recognize whether and to what extent attentional control is necessary, leading to effective attentional control (Adams & Gaspelin, 2020, 2021; Boureau et al., 2015; Webb & Graziano, 2015). Supporting this idea, previous research has revealed that attentional monitoring is crucial for controlling future behaviors and decisions (Wilterson et al., 2021; Wilterson & Graziano, 2021) and that interventions (e.g., neurofeedback and meditation) to enhance attentional monitoring abilities significantly improve attentional control (deBettencourt et al., 2015; MacLean et al., 2010; Verhaeghen, 2021; Ziegler et al., 2019). These findings highlight the importance of accurate attentional monitoring for anxious individuals to be able to control their maladaptive attentional bias and thereby break the vicious circle of anxiety.

However, despite the importance of this topic, little is currently known about whether and how anxious individuals monitor their attentional bias. Instead, previous research has primarily investigated the relationship between anxiety and attentional control (Cisler & Koster, 2010; Shi et al., 2019). For example, a growing body of research has shown that anxious individuals exhibit worse attentional control than nonanxious individuals, despite their crucial need for better attentional control (Berggren & Derakshan, 2013;

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Bishop, 2009; Georgiou et al., 2005; Hur et al., 2019; Shi et al., 2019; Valadez et al., 2022). Theories of attentional processes in anxiety suggest that anxiety impairs executive functions related to attentional control, such as inhibition, shifting, and updating (e.g., attentional control theory; Eysenck et al., 2007, 2023). However, as the processes supporting attentional monitoring and control are distinct but closely associated (Boldt & Gilbert, 2022; Fleming, 2024; Nelson & Narens, 1990; Shimamura, 2000), investigating attentional monitoring in anxiety is crucial to fully understand attentional processes in anxiety.

Given these points, the present study directly examines attentional monitoring in anxiety. By adopting a novel approach involving average facial expression and attentional allocation judgments, we tested how accurately individuals monitor their attentional bias toward threat-related stimuli and whether this ability is associated with anxiety levels. Initially, we measured the strength of attentional bias using an average facial expression judgment task. Two faces with different intensities of anger (i.e., near neutral and full-blown-angry faces) were presented simultaneously, and participants were asked to judge the average facial expression of the two faces. According to previous studies, attentional bias to faces with an extreme intensity of emotion leads to average facial expression judgments that are biased toward that emotion (Awad et al., 2023; Goldenberg et al., 2021, 2022). This close relationship between attentional bias and average judgments enables us to infer the strength of attentional bias toward a face with an extreme intensity of anger from the average facial expression judgment (Yang et al., 2013). For example, a greater bias toward anger in the average facial expression judgment may indicate a more pronounced attentional bias toward a face with an extreme intensity of anger.

Subsequently, to measure attentional monitoring abilities, we asked participants to report their relative attentional allocation between the two faces (e.g., 39% vs. 61%). If participants accurately monitor their attentional allocation, they should report a greater attentional allocation to a face with an extreme intensity of anger when exhibiting a greater bias toward anger in the average judgment. This attentional monitoring ability was evaluated by measuring attentional monitoring bias and sensitivity. First, attentional monitoring bias was examined by averaging the bias toward anger in the attentional monitoring judgments across trials. This metric represents participants' awareness of the overall direction and magnitude of their attentional bias: Positive or negative biases indicate overestimation or underestimation of attentional bias toward anger, respectively. Second, attentional monitoring sensitivity was estimated by calculating the correlation coefficient between the average and attentional monitoring judgments across trials, which serves as an indicator of how sensitively participants monitored trial-by-trial variations in their attentional bias.

Based on the assessment of attentional monitoring ability, we investigated the relationship between anxiety and attentional monitoring. We hypothesized that participants with higher anxiety levels would exhibit abnormal attentional monitoring (e.g., a greater monitoring bias or lower monitoring sensitivity), which could then explain why anxious individuals exhibit impaired attentional control. To test this hypothesis, we computed the correlation coefficient between attentional monitoring abilities (i.e., monitoring bias and sensitivity) and anxiety levels (i.e., state and trait anxiety scores) measured using the State-Trait Anxiety Inventory (STAI; Spielberger, 1983).

Method

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All raw data and analysis scripts are available in the Open Science Framework (https://osf.io/5xp8b/; Kim et al., 2024). This study was not preregistered.

Participants

Seventy participants (20 men and 50 women; age: $M = 23.26$ years, $SD = 2.41$ years, range = 19–30 years; recruited in 2023–2024) took part in the study, all of whom reported normal or corrected-to-normal vision. The experimental procedures were approved by the Institutional Review Board of Yonsei University, and all participants provided written informed consent. All participants were recruited from Yonsei University and were paid for their participation. We determined the sample size based on a sequential Bayes factor (BF) design analysis (Schönbrodt & Wagenmakers, 2018). We initially recruited a minimum sample size of 50 and then increased it until we acquired moderate evidence either for ($BF_{10} > 3$) or against ($BF_{10} < 1/3$) the correlations between anxiety scores (state and trait anxiety) and three main experimental measures (attentional bias, monitoring bias, and monitoring sensitivity). Ultimately, we collected data from 70 participants and excluded two whose average judgment precision^{-1} (*SD* of average judgments) was more than 2 *SD*s away from the sample mean, indicating unusual response strategies or noncompliance with instructions.

With the remaining 68 participants, we obtained enough evidence for the correlations between anxiety and attentional bias (state anxiety: $BF_{10} = 15.26$; trait anxiety: $BF_{10} = 8.26$) and between anxiety and monitoring bias (state anxiety: $BF_{10} = 63.51$; trait anxiety: $BF_{10} = 3.32$), whereas the BF of the correlation between anxiety and monitoring sensitivity did not meet the criteria (state anxiety: $BF_{10} = 0.44$; trait anxiety: $BF_{10} = 1.03$). However, we found strong evidence against the negative correlation between anxiety and monitoring sensitivity (state anxiety: $BF_{10} = 0.06$; trait anxiety: $BF_{10} = 0.05$) and, therefore, stopped data collection, given that the purpose of this study is to examine whether individuals with higher anxiety levels exhibit lower attentional monitoring abilities.

Apparatus and Stimuli

We conducted the experiment using MATLAB (The MathWorks, Natick, Massachusetts, United States) with the Psychophysics Toolbox 3 (Brainard, 1997; Pelli, 1997). Stimuli were presented on a cathode-ray tube monitor (1,280 × 960 resolution; 85 Hz refresh rate) in a dark room. A viewing distance of 60 cm was maintained with a head-and-chin rest. Stimuli were displayed on a gray background (mean luminance = 26 cd/m^2).

For an average facial expression judgment task, face stimuli were selected from a morphed face stimulus set used by Sun and Chong (2020). We used 101 frontal-view face stimuli generated by morphing neutral and full-blown-angry faces with different ratios of anger intensity from 0% (neutral) to 100% (full-blown anger). The faces were cropped into an oval shape, subtending $4.57° \times 6°$. A black crosshair (subtending $0.6° \times 0.6°$) was present at the center of the display, and participants were asked to fixate on the center of the crosshair. Two target faces were presented at iso-eccentric locations to the left and right (±7°) of the crosshair. A probe face (subtending 4.57° × 6°) for the average facial expression judgment was presented at the center of the display.

Procedure

Participants completed the STAI first and then performed an experimental task.

STAI

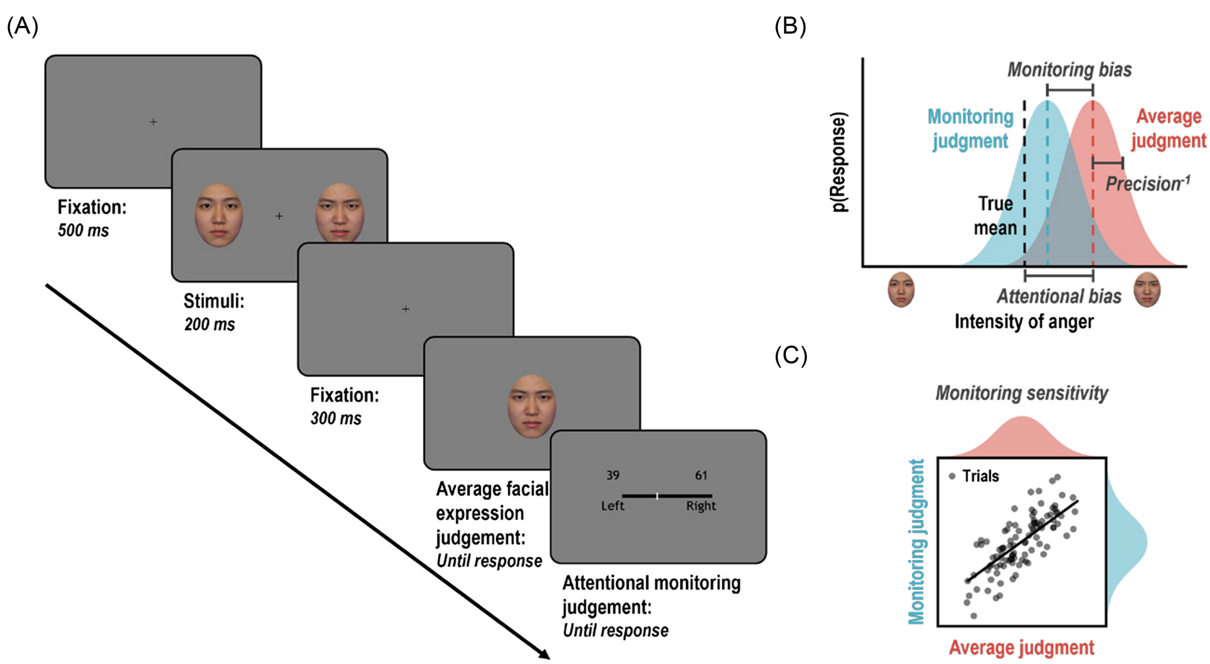
Participants' state and trait anxiety levels were assessed using the Korean version of the STAI (Hahn et al., 1996; Spielberger, 1983). The STAI consists of two sets of 20 items rated on a 4-point scale from 1 (*almost never*) to 4 (*almost always*) that assess state (*how you feel right now*; STAI-S) and trait (*how you generally feel*; STAI-T) anxiety levels. The STAI is a widely used measure of anxiety with well-established validity, test–retest reliability, and internal consistency (Barnes et al., 2002; Spielberger, 1983). We assessed both state and trait anxiety levels to enhance the generalizability of our findings about the correlation between anxiety and experimental measures. We expected a similar pattern of results between state and trait anxiety because they are highly correlated in the absence of experimental manipulations of state anxiety and influence attentional processes in similar ways (Bar-Haim et al., 2007; Shi et al., 2019).

Experimental Task for Attentional Bias and Monitoring Assessments

The experiment consisted of four blocks, each containing 100 trials separated by breaks. A schematic trial sequence is shown in Figure 1A. Each trial began with a 500-ms fixation, followed by the presentation of two target faces for 200 ms. Participants were instructed to fixate on a black crosshair at the center of the display. Considering that the initiation of saccades requires approximately 250 ms (Mayfrank et al., 1987), the duration of target presentation was assumed to be brief enough to prevent a target-directed saccade.

There were two target conditions, designed for test and control trials, and each contained 200 trials. In the test trials, we presented two faces with different intensities of anger (one level: 10% vs. 90%). In the control trials, we presented two faces with the same intensity of anger (five levels: 10% vs. 10%, 30% vs. 30%, 50% vs. 50%, 70% vs. 70%, and 90% vs. 90%). Each level of control trials included 40 trials. These control trials were introduced to prevent participants from noticing that there was only one level of test trials and to separate attentional bias from decisional or memory biases (see the Data Analysis section). The test and control trials were randomly interleaved. After a 300-ms fixation, a probe face was

Figure 1
Schematic Trial Sequence and Experimental Measures



Note. (A) Schematic trial sequence of an experiment. After a 500-ms fixation, two target faces were presented for 200 ms. First, participants were asked to report the average facial expression of the two faces by adjusting the facial expression of a probe face. Next, they were required to report relative attentional allocation to left and right faces using a slider (e.g., 39% vs. 61%). (B) Response distributions of average and monitoring judgments. Attentional bias is the difference between the mean average judgment and the true mean of the two target faces (i.e., 50%). Average judgment precision is SD^{-1} of average judgments. Monitoring bias is the difference between the mean monitoring and average judgments. (C) Monitoring sensitivity is the correlation coefficient between average and monitoring judgments across trials. See the online article for the color version of this figure.

presented at the center of the display. The initial intensity of anger on the probe face was randomly selected from 0% to 100% in 1% increments. Participants were asked to report the average facial expression of the two faces by adjusting the facial expression of the probe face using a mouse; moving the mouse upward increased the intensity of anger on the probe face, while moving it downward decreased the intensity. The intensity of anger on the probe face was adjusted from 0% to 100% in 1% increments. Next, a horizontal slider was presented, and participants were asked to report relative attentional allocation to the left and right target faces using a mouse (e.g., 39% vs. 61%). Specifically, they were instructed to respond with 50% versus 50% when both faces were equally reflected in the average judgment and with 100% versus 0% when only the left face was reflected.

Data Analysis

We calculated participants' total summed state and trait anxiety scores. Total state and trait anxiety scores range from 20 to 80, with higher scores indicating higher levels of anxiety. Two participants each had one missing response on the STAI-S, which can be considered random missing data (i.e., less than 10% missing on any of the questionnaires; Grös et al., 2007). These missing responses were replaced with the within-participant mean response (i.e., the average of the items they answered; Bernaards & Sijtsma, 1999).

We derived measures of attentional bias, average judgment precision, monitoring bias, and monitoring sensitivity for each participant (Figure 1B and 1C). To derive attentional bias, we first corrected participants' average facial expression judgments to consider the potential compounding effects of memory or decisional biases. Average judgments in test trials can be influenced not only by attentional bias but also by other types of biases arising during memory retention or decision-making processes. To distinguish the effects of attentional bias from other types of biases, we subtracted participants' response bias in the control trials (i.e., the mean difference between the average judgments and the true mean of the two target faces), which is assumed to be influenced by memory or decisional biases but not attentional bias, from their average judgments in the test trials. Then, we quantified attentional bias by calculating the difference between the mean corrected average judgment and the true mean of the two target faces (i.e., 50%). No attentional bias would indicate equal attentional allocation between the two target faces, whereas either positive or negative biases would indicate attentional bias toward or away from a face with an extreme intensity of anger, respectively.

Next, average judgment precision is defined as SD^{-1} of the average facial expression judgments in the test trials. A smaller *SD* would indicate a narrower response distribution (smaller trial-by-trial variation) and, thus, a more precise average judgment, regardless of participants' attentional bias. Average judgment precision can be influenced by trial-by-trial variability in attentional bias and noise in the average judgment process (MacLeod et al., 2019).

To derive monitoring bias, we first converted participants' monitoring judgments in the test trials to the intensity of anger scale based on the weighted average assumption as follows: Monitoring judgment = 90 × (attentional allocation on a face with 90% intensity of anger/100) + 10 × (attentional allocation on a face with 10% intensity of anger/100). Then, we quantified monitoring bias by calculating the difference between the mean monitoring and average judgments. No monitoring bias would reflect accurate monitoring of the overall direction and magnitude of attentional bias, whereas either positive or negative biases would reflect overestimation or underestimation of attentional bias toward a face with an extreme intensity of anger, respectively.

Last, we derived monitoring sensitivity by calculating Pearson's correlation coefficient between average and monitoring judgments across trials, which indicates how sensitively participants monitored trial-by-trial variations in their attentional bias.

The primary analyses were Bayesian analyses, which we performed using JASP version 0.19.0 (JASP Team, 2024). We examined whether mean attentional bias, monitoring bias, and monitoring sensitivity differed from zero using a Bayesian one-sample *t* test (default priors in JASP) and whether the experimental measures were correlated with each other using a Bayesian Pearson's correlation (default priors in JASP). Additionally, also using a Bayesian Pearson's correlation, we investigated whether state and trait anxiety scores from the STAI were correlated with attentional bias, average judgment precision, monitoring bias, and monitoring sensitivity. All tests were conducted using two-tailed values, but we additionally reported one-tailed BF_{10} values for tests with an a priori directional hypothesis. BFs represent the relative predictive performance of the alternative (H_1) and null (H_0) hypotheses. For instance, a BF_{10} of 3 means that the data are three times more likely under H_1 than under H_0.

Results

STAI

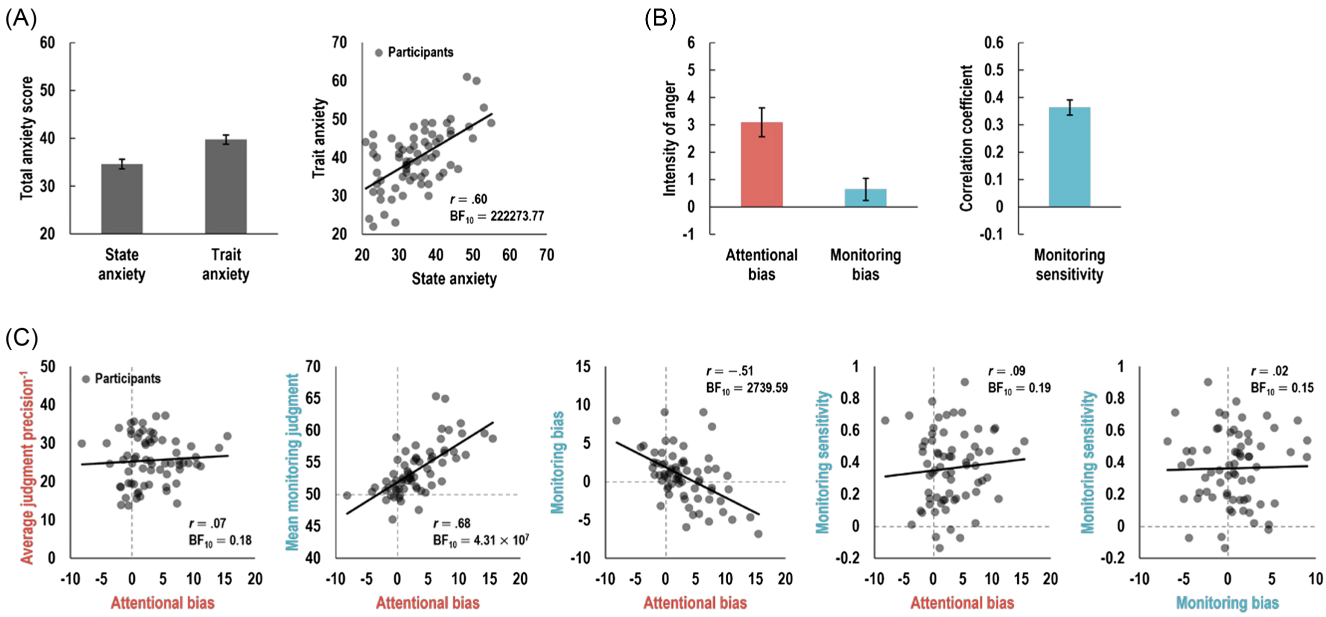
As shown in Figure 2A, participants' mean state and trait anxiety scores were 34.65 (SD = 8.22, range = 21–55) and 39.74 (SD = 7.86, range = 22–61), respectively. We found strong evidence that the state and trait anxiety scores were positively correlated with each other across participants (r = .60, BF_{10} = 222273.77).

Experimental Measures

As shown in Figure 2B, we found strong evidence for the difference of attentional bias from zero (M = 3.09, SD = 4.35; BF_{10} = 89151.88), which demonstrates a group-level attentional bias toward a face with an extreme intensity of anger. Additionally, we found strong evidence against the difference of monitoring bias from zero (M = 0.64, SD = 3.35; BF_{10} = 0.04), indicating no monitoring bias and accurate monitoring of the overall direction and magnitude of attentional bias on the group level. We also obtained strong evidence for the difference of monitoring sensitivity from zero (M = .36, SD = .23; $BF_{10} = 1.17 \times 10^{17}$), which suggests that participants were able to monitor trial-by-trial variations in their attentional bias.

As shown in Figure 2C, we also examined the correlations between experimental measures. First, we found moderate evidence against the correlation between attentional bias and average judgment precision^{-1} (r = .07, BF_{10} = 0.18), suggesting that contributing factors to attentional bias and average judgment precision (e.g., trial-by-trial variability in attentional bias) are independent. Importantly, we found strong evidence that attentional bias was positively correlated with the mean monitoring judgment (r = .68, $BF_{10} = 4.31 \times 10^7$). This result indicates that participants with

Figure 2
Survey and Experimental Results



Note. (A) Mean state and trait anxiety scores and their correlation across participants. (B) Mean attentional bias, monitoring bias, and monitoring sensitivity. Error bars indicate standard error of the mean. (C) Correlations between experimental measures. Each dot represents an individual participant, and black lines indicate the best fitting regression lines. BF = Bayes factor. See the online article for the color version of this figure.

greater attentional bias reported greater attentional allocation to a face with an extreme intensity of anger, suggesting accurate attentional monitoring on the group level. However, we found strong evidence that attentional bias was negatively correlated with monitoring bias ($r = -.51$, $BF_{10} = 2739.59$), demonstrating that participants with either greater or less attentional bias tended to underestimate or overestimate their attentional bias, respectively. Additionally, we obtained moderate evidence against the correlations between attentional bias and monitoring sensitivity ($r = .09$, $BF_{10} = 0.19$) and between monitoring bias and sensitivity ($r = .02$, $BF_{10} = 0.15$), suggesting independence between these measures.

Correlations Between Anxiety and Experimental Measures

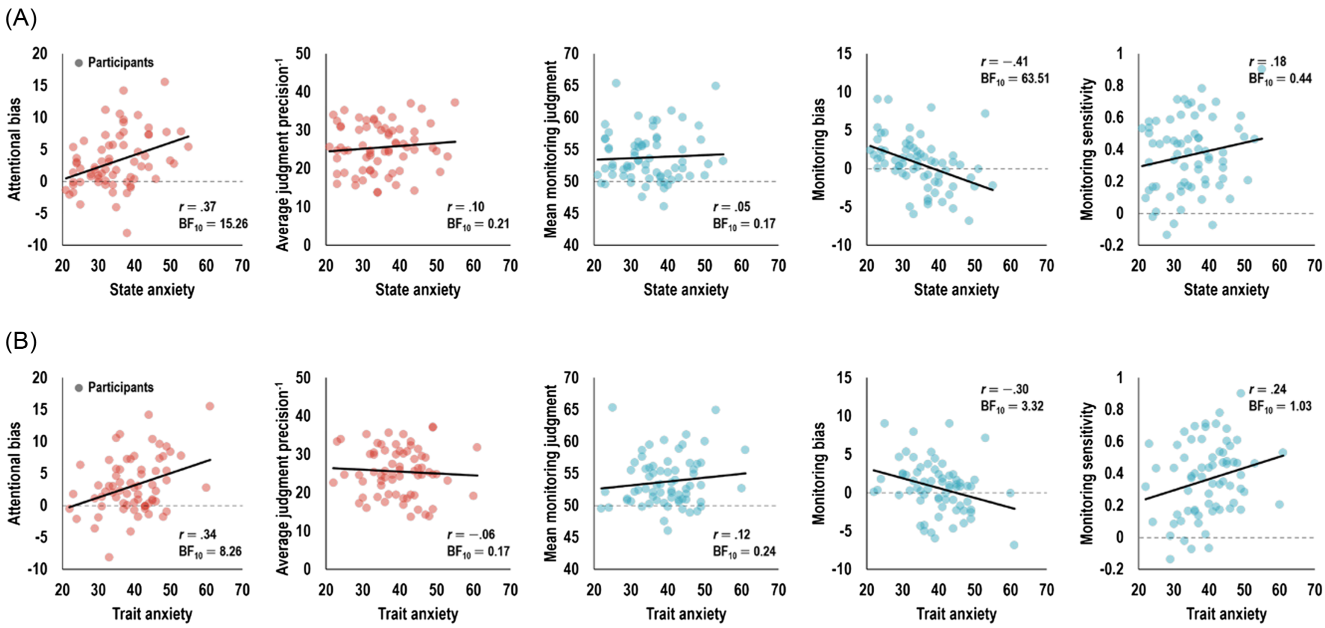
As shown in Figure 3, we investigated whether state and trait anxiety scores were correlated with the experimental measures, namely, attentional bias, average judgment precision, monitoring bias, and monitoring sensitivity. We observed similar patterns of results between state (Figure 3A) and trait anxiety (Figure 3B), which may be attributable to the high positive correlation between them. First, we found that anxiety was positively correlated with attentional bias (state anxiety: $r = .37$, $BF_{10} = 15.26$; trait anxiety: $r = .34$, $BF_{10} = 8.26$), which replicates previous findings that individuals with higher levels of anxiety tend to exhibit greater attentional bias toward an angry face. However, we obtained moderate evidence against the correlation between anxiety and average judgment precision^{-1} (state anxiety: $r = .10$, $BF_{10} = 0.21$; trait anxiety: $r = -.06$, $BF_{10} = 0.17$), indicating that the average judgment precision of anxious individuals might not be impaired despite their greater attentional bias. This result also suggests that trial-by-trial variability in attentional bias may not differ according to anxiety levels.

Importantly, we found moderate evidence against the correlation between anxiety and the mean monitoring judgment (state anxiety: $r = .05$, $BF_{10} = 0.17$; trait anxiety: $r = .12$, $BF_{10} = 0.24$), indicating that individuals' monitoring judgment did not reflect the positive correlation between anxiety and attentional bias. This may explain the negative correlation between anxiety and monitoring bias (state anxiety: $r = -.41$, $BF_{10} = 63.51$; trait anxiety: $r = -.30$, $BF_{10} = 3.32$), which suggests that individuals with either higher or lower anxiety levels tend to underestimate or overestimate their attentional bias, respectively.[1] However, we obtained no conclusive evidence for the correlation between anxiety and monitoring sensitivity (state anxiety: $r = .18$, $BF_{10} = 0.44$; trait anxiety: $r = .24$, $BF_{10} = 1.03$). To test our a priori directional hypothesis that individuals with higher anxiety levels would exhibit lower attentional monitoring abilities, we further computed one-tailed BF_{10} and found strong evidence against the negative correlation between anxiety and monitoring sensitivity (state anxiety: $r = .18$, $BF_{10} = 0.06$; trait anxiety: $r = .24$, $BF_{10} = 0.05$), which suggests that high anxiety levels do not impair one's ability to monitor trial-by-trial variations in attentional bias.

[1] As an exploratory analysis, we conducted a Bayesian multimodel linear regression analysis to further examine the unique contribution of anxiety to monitoring bias beyond the contribution of attentional bias (see Supplemental Analysis 1). We found some evidence for the unique contribution of state anxiety, but not trait anxiety, to monitoring bias beyond the contribution of attentional bias. However, these findings should be interpreted with caution, as the evidence remains anecdotal. Future research will be necessary to further clarify the unique contribution of anxiety to monitoring bias.

Figure 3

Correlations Between Anxiety and Experimental Measures



Note. (A) Correlations between state anxiety and experimental measures. (B) Correlations between trait anxiety and experimental measures. Each dot represents an individual participant, and black lines indicate the best fitting regression lines. BF = Bayes factor. See the online article for the color version of this figure.

Discussion

The present study investigates the relationship between anxiety and metacognitive monitoring of attentional bias toward threat-related stimuli. Adopting a novel approach that involves average facial expression and attentional allocation judgments, we first confirmed that anxiety levels are positively correlated with attentional bias. This finding aligns with previous research showing that individuals with higher levels of anxiety exhibit greater attentional bias toward threat-related stimuli (Bar-Haim et al., 2007; Cisler & Koster, 2010; Hur et al., 2019; Mathews et al., 1997; Valadez et al., 2022). Additionally, we found that anxiety levels were not correlated with average judgment precision, suggesting that trial-by-trial variability in attentional bias may not differ according to anxiety levels (but see MacLeod et al., 2019).

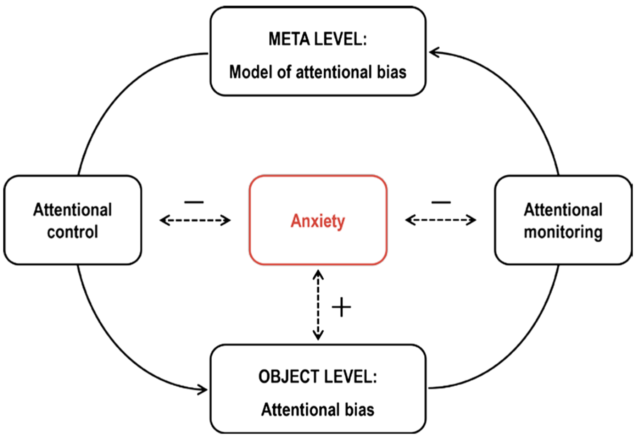
Importantly, we found that anxiety levels were negatively correlated with attentional monitoring bias. Specifically, individuals with higher anxiety levels tended to underestimate their attentional bias toward a face with an extreme intensity of anger. This finding may explain why anxious individuals exhibit impaired attentional control. Introspective awareness of one's own attentional bias is crucial for recognizing whether and to what extent attentional control is needed (Adams & Gaspelin, 2020, 2021; Kim & Chong, 2025; Webb & Graziano, 2015; Wilterson et al., 2021; Wilterson & Graziano, 2021). Accordingly, it is likely that anxious individuals underestimate their attentional bias toward threat, leading to a misjudgment of the necessity for attentional control.

In contrast to monitoring bias, monitoring sensitivity was not negatively correlated with anxiety levels. This result suggests that high anxiety levels might not impair the ability to monitor trial-by-trial variations in attentional bias, despite the underestimation of the overall magnitude of attentional bias. Indeed, we confirmed that monitoring bias and sensitivity were not correlated with each other. This dissociation suggests that fine-grained measurements and models are needed to further clarify the relationship between anxiety and attentional monitoring.

Overall, the present study underscores the necessity of incorporating attentional monitoring processes into existing models of attentional processes in anxiety, which have focused on attentional control (Cisler & Koster, 2010; Eysenck et al., 2007, 2023; Shi et al., 2019). Relatedly, a wealth of research demonstrates that the processes that support metacognitive monitoring and control are distinct but closely related (Boldt & Gilbert, 2022; Fleming, 2024; Nelson & Narens, 1990; Shimamura, 2000). For example, the seminal model by Nelson and Narens (1990) describes metacognition as the interplay between the object and meta levels. Object-level processes are monitored by the meta level (metacognitive monitoring), and based on this monitoring, the meta-level processes control the object-level processes (metacognitive control). In support of this model, previous studies have revealed that metacognitive monitoring is important for the control of future behaviors and decisions (Boldt & Gilbert, 2022; Boureau et al., 2015; Kim & Chong, 2024; Resulaj et al., 2009; Wilterson et al., 2021; Wilterson & Graziano, 2021). Therefore, to understand the whole picture of attentional processes in anxiety, it is necessary to consider both attentional monitoring and control (Figure 4).

And indeed, the consideration of attentional monitoring provides testable explanations for the seemingly inconsistent findings of previous studies. For example, the success or failure of attentional monitoring can determine whether attentional bias is followed by

Figure 4
Attentional Monitoring and Control Model



Note. A model of attentional processes in anxiety based on the model of metacognition proposed by Nelson and Narens (1990). Attentional bias at the object level is re-represented at the meta level through an attentional monitoring process. Based on this meta-level representation (an internal model of attentional bias), an attentional control process modulates attentional bias. Anxiety is positively correlated with attentional bias and negatively correlated with both attentional monitoring and control. See the online article for the color version of this figure.

compensatory mechanisms. This may explain why some anxious individuals exhibit maintenance of attention on threat while others exhibit threat avoidance (McNally, 2019; Mogg & Bradley, 2016). Similarly, attentional monitoring can determine whether anxious individuals exhibit reduced or increased prefrontal activity, reflecting either the reduced recruitment of attentional control mechanisms or the increased recruitment of inefficient compensatory mechanisms, respectively (Berggren & Derakshan, 2013; Bishop, 2009; Eysenck et al., 2023; Hur et al., 2015; Valadez et al., 2022).

However, it is important to note that the present study does not directly examine the relationship between attentional monitoring and control. To address this limitation, future studies should directly test whether and how strongly attentional monitoring and control are associated with each other. Specifically, in the present study, we sought to minimize the influence of attentional control on average facial expression judgments so that we could interpret errors in average facial expression judgments as indicating attentional bias rather than a combination of attentional bias and control. To reduce the potential influence of attentional control, we selected a short target presentation time of 200 ms, which is too brief for reactive attentional control to take effect (Derryberry & Reed, 2002). In addition, the location of the angrier face was randomized across trials and the angrier face served as the target rather than a distractor, which further minimizes the likelihood of proactive attentional control (Braver, 2012). Therefore, future research employing experimental designs (e.g., longer target presentation times) or measures (e.g., electroencephalography) that specifically examine proactive and reactive attentional control (Gaspar & McDonald, 2018) will be necessary to clarify the relationship between attentional monitoring and control in anxiety.

The present study also examines local metacognitive experiences during tasks rather than global metacognitive knowledge about attentional bias. Previous research suggests that local, implicit, and trial-level metacognitive experiences and global, explicit, and task-level metacognitive knowledge are dissociable (Dijkstra et al., 2022; Flavell, 1979; Seow et al., 2021). Such dissociation has been observed across various domains, such as visual perception (Kim & Chong, 2024; Mazor & Fleming, 2022; Rouault & Fleming, 2020) and memory (Lehmann et al., 2022; McWilliams et al., 2023). These findings suggest that local metacognitive experiences and global metacognitive knowledge about attentional bias may also be dissociated. For example, anxious individuals might overestimate, rather than underestimate, their attentional bias toward threat at the level of global metacognitive knowledge. Further research is needed to investigate global metacognitive knowledge about attentional bias in anxiety and its relationship with local metacognitive experiences.

To examine attentional bias and monitoring, we adopted a novel approach that utilizes average facial expression and attentional allocation judgments. We quantified the magnitude of attentional bias on a trial-by-trial basis and compared it with attentional allocation judgment on the same scale. This fine-grained measurement enabled us to examine attentional bias, average judgment precision, monitoring bias, and monitoring sensitivity separately. Furthermore, our experimental design differentiates the effects of anxiety on attentional bias from those on other types of biases, such as perceptual, memory, and decisional biases. For example, the possibility that anxious individuals perceive target faces as angrier than they actually are (Staugaard, 2010) can be ruled out by using a probe face. This is because such perceptual bias could influence the perception of both the target and probe faces, thereby offsetting its effect (Firestone & Scholl, 2016). Additionally, the correction procedure, which subtracts the average judgments in control trials from those in test trials, helps minimize the possibility of memory bias (e.g., anxious individuals remembering angry faces as angrier than they actually were) and decisional bias (e.g., anxious individuals preferring to respond with an angrier face).

Given that several recent studies have suggested that traditional reaction time-based measures of attentional bias (e.g., a dot-probe task) may be unreliable (MacLeod et al., 2019; McNally, 2019), our approach could serve as a possible alternative or complement to the assessment of attentional bias in anxiety. However, as our sample was limited to college students, further research in different populations (e.g., older or clinical populations) is needed to verify the reliability and generalizability of our approach and findings.

In conclusion, this study's investigation of the relationship between anxiety and attentional monitoring reveals that anxiety is negatively correlated with monitoring bias but not with monitoring sensitivity. These results suggest that despite their intact ability to monitor trial-by-trial variations in attentional bias, anxious individuals underestimate their greater attentional bias toward threat-related stimuli, which may lead to impaired attentional control. Our findings highlight the importance of considering attentional monitoring processes to fully comprehend the relationship between attention and anxiety. We also anticipate that a deeper understanding of attentional monitoring in anxiety could pave the way for new interventions aimed at enhancing attentional monitoring (e.g., feedback and training; deBettencourt et al., 2015; MacLean et al., 2010; Verhaeghen, 2021; Ziegler et al., 2019), thereby improving attentional control and reducing maladaptive attentional bias in the treatment of anxiety disorders.

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