How state anxiety and attentional bias interact with each other: The moderating effect of cognitive appraisal

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Abstract

In the present study, we conducted four experiments to explore how state anxiety influences attentional bias, and vice versa, as well as the moderating effect of cognitive appraisal in this relationship. Experiment 1 focused on whether induced state anxiety could lead to attentional bias. Experiment 2 explored the influence of attentional bias on state anxiety under stressful conditions. Experiments 3 and 4 investigated the moderating effect of cognitive appraisal on the interaction between state anxiety and attentional bias. Our main findings were that state anxiety directly leads to attentional bias, whereas negative attentional bias increases state anxiety under stressful conditions. Moreover, cognitive appraisal moderates the influence of attentional bias on state anxiety, but not the reverse influence. The implications of our study are that it provides empirical evidence for the interaction between state anxiety and attentional bias, and also that it offers insight into the different moderating effects of cognitive appraisal on the relationship.

Keywords State anxiety · Attentional bias · Cognitive appraisal · Interaction · Moderating effect

Many people suffer from the dysfunction of anxiety. Given the ubiquitous nature of anxiety, a thorough understanding of its causes is imperative. However, despite the importance of this topic, fundamental questions remain about how anxiety is maintained and exacerbated over time.

Among many possible causes, there is a consensus at the theoretical level that anxiety is associated with biases in processing threat-related information (Eysenck, 1992; Mogg & Bradley, 1998; Williams, Watts, MacLeod, & Mathews, 1997). Specifically, the attentional system of anxious individuals is distinctively biased in favor of threat-related stimuli in the environment (Beck, 1976; Beck & Clark, 1997). Nevertheless, the wide range of empirical studies regarding threat-related biases in anxiety offer a somewhat confusing picture, plagued by contradictory findings that lack

unambiguous explanation. In addition, Van Bockstaele et al. (2014) have claimed that the relation between anxiety and attentional bias is unlikely to be unidirectional, but bidirectional. In fact, some well-known cognitive theories of anxiety also incorporate the view of the bidirectional relationship between anxiety and attentional bias (Eysenck, 1992, 1997; Mogg & Bradley, 1998; Williams et al., 1997). It is claimed that this bidirectional relationship not only puts the confusing empirical findings in order, but also adequately interprets why anxiety is maintained and exacerbated over time. However, in a review of the related literature, we found that the bidirectional relationship is proposed mainly in the context of anxiety disorders or trait anxiety, rather than state anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Van Bockstaele et al., 2014). Since anxiety disorders and trait anxiety are already involved in such a bidirectional loop, it is almost impossible to observe the interaction between anxiety and attentional bias, because they are always associated with each other. This is probably the reason for regarding the nature of the interaction between anxiety and attentional bias in this way. Some findings seem to suggest that anxiety can precede the onset of attentional bias (Bar-Haim et al., 2007), whereas others imply that attentional bias precedes anxiety in time (Bar-Haim, 2010; MacLeod, Rutherford, Campbell, Ebsworthy, & Holker, 2002). It is

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possible that the inconsistent findings are actually caused by the measuring order—that is, whether anxiety or attentional bias is measured first may to a large extent determine which one appears to be the causing variable. Thus, it still remains unclear whether anxiety truly leads to an attentional bias, and vice versa.

Moreover, anxiety may be caused by different cognitive processes, such as memory and interpretation (e.g., Beck & Clark, 1997; Eysenck, 1992, 1997; Mogg & Bradley, 1998); in other words, attentional bias is associated not only with anxiety, but also with memory, interpretation, appraisal, and so forth. According to Williams et al. (1997), trait anxiety reflects a proneness to direct cognitive resources either toward or away from threatening stimuli. Eysenck (1992) argued that anxiety disorders develop if a cognitively vulnerable individual is exposed to stressful life events. Like the model of Williams et al. (1997), the cognitive motivational view identifies two functional systems that are implicated in attentional bias: a valence evaluation system and a goal engagement system (Mogg & Bradley, 1998), where the threat value of a stimulus is appraised by the valence evaluation system. In general, if people do not appraise stressful life events as stressful, and if they do not appraise threat as a threat, then they may not develop anxiety. However, it remains unclear how cognitive appraisal operates in the interaction between anxiety and attentional bias.

In the present article, we aimed to explore whether anxiety truly influences attentional bias, and vice versa—in particular, how cognitive appraisal operates in the influence of anxiety on attentional bias, and vice versa. To achieve this purpose, we opted to study state anxiety. This is defined as a feeling of anxiety in response to an external stressor or stressful event, which can be induced by a situation or by particular stimuli (Barlow, 2001; Montorio, Nuevo, Cabrera, Marquez, & Izal, 2015; Spielberger, 1971). According to Eysenck (1997), “clinical anxiety develops when there is a positive feedback loop between these biases and state anxiety, in which high levels of anxiety exaggerate the biases, and the exaggerated biases increase state anxiety” (p. 119). This formulation suggests that attentional bias is regarded as a maintaining or exacerbating factor for anxiety disorders, and that state anxiety is the foundation of the positive feedback loop. Meanwhile, *cognitive appraisal* refers to a process through which a person evaluates whether a particular encounter with the environment is relevant to his or her wellbeing, and if so, in what way (Folkman, Lazarus, Dunkel-Schetter, DeLongis, & Gruen, 1986; Folkman, Lazarus, Gruen, & DeLongis, 1986).

A number of empirical studies have examined the unidirectional relationship between anxiety and attentional bias. On the one hand, in a meta-analysis of 172 studies, Bar-Haim et al. (2007) found that individuals with anxiety disorders, such as generalized anxiety disorder, social anxiety disorder, and panic attacks, have significantly more of an attentional bias to threatening stimuli than do those individuals without anxiety disorders. For example,

Ononaiye, Turpin, and Reidy (2007) and Webb, Ononaiye, Sheeran, Reidy, and Lavda (2010) found that individuals with social anxiety have an attentional bias toward threatening words. Elssesser, Heuschen, Pundt, and Sartory (2006) and Teachman (2005) reported that individuals with panic disorder have an attentional bias toward threatening stimuli generally. Some other studies have demonstrated that individuals with trait anxiety also have an attentional bias toward threatening stimuli (Derakshan & Koster, 2010; Koster, Verschuere, Crombez, & Van Damme, 2005; Salemink, Ma, & Kindt, 2007). Accordingly, we hypothesized that state anxiety would increase attentional bias toward negative stimuli (Hypothesis 1, H1).

On the other hand, some studies have shown that attentional bias affects anxiety. MacLeod et al. (2002) induced attentional bias toward negative or neutral words through the attentional bias modification procedure and found that individuals induced with a negative attentional bias demonstrated significantly higher anxiety after the same stressful condition than did individuals induced with a neutral attentional bias. MacLeod et al. (2002) considered that attentional bias toward negative information affects the vulnerability to anxiety. In addition to the direct study of the ways that attentional bias affects anxiety, a group of studies have focused on negative attentional bias correction—that is, on positive or neutral attentional bias training to treat anxiety disorders. Many studies have shown that negative attentional bias modification can effectively change the attention pattern and alleviate anxiety disorders (Bar-Haim, 2010; Hakamata et al., 2010). Accordingly, we hypothesized that negative attentional bias would increase state anxiety under stressful conditions (Hypothesis 2, H2).

In addition, according to appraisal theories of anxiety (Daghighi, 1994), the appraisal of a stimulus as threatening leads to a set of physiological reactions and their concomitant sensations, and also serves to put the system into an anxious state in which it is ready to deal with the threatening stimulus. In line with this argument, the cognitive system invests a certain amount of resources in the processing of the threatening stimulus, and the selective attention system is concerned with monitoring and gathering threat-related information. Therefore, anxiety is associated with attentional bias within a cognitive appraisal framework. From the perspective of empirical research, some studies have shown that anxiety and physiological changes are influenced not only by situational factors but also by cognitive appraisal (Barrett, 2006; Mauss, Cook, Cheng, & Gross, 2007). Jamieson, Nock, and Mendes (2012) found that changes in cognitive appraisal of a stress task could improve cardiovascular function and reduce attentional bias to negative stimuli. Kim, Kim, and Kim (2016) found that participants' attentional bias toward anger pictures decreased after reducing cognitive appraisal of the negative emotion, and that such bias increased after increasing cognitive appraisal of the negative emotion. Accordingly, we

hypothesized that cognitive appraisal would moderate the relationship between state anxiety and attentional bias (Hypothesis 3, H3).

We conducted four experiments to address these research questions. Experiments 1 and 2 were conducted to examine the interaction between state anxiety and attentional bias, and Experiments 3 and 4 were administered to further examine moderating effects on the interaction between state anxiety and attentional bias. H1 and H2 were examined in Experiments 1 and 2, respectively. We expected that Experiments 3 and 4 might further verify the stability of the results from Experiments 1 and 2, as well as provide novel evidence for the moderating effect of cognitive appraisal on the relationship between state anxiety and attentional bias (H3).

Experiment 1

In Experiment 1, we used an anxiety induction procedure (Montorio et al., 2015) in the laboratory to manipulate state anxiety, exploring the influence of state anxiety on attentional bias. The hypothesis to be examined was that high state anxiety increases the attentional bias toward negative stimuli (H1).

Method¹

Participants

A total of 97 university students participated in Experiment 1 (54 males, 43 females; $M_{\text{age}} = 21.31$ years, $SD = 2.69$).² They were randomly assigned to the experimental group ($N = 48$) or the control group ($N = 49$).

Procedure and materials

All participants completed the Chinese version of the Trait Anxiety Inventory (TAI) online when they were recruited, which has good reliability (Cronbach's $\alpha = .88$) and validity (Spielberger, 1971). They provided written informed consent after they arrived at the psychology laboratory, as did the participants in the following three experiments. E-Prime 2.0

was used to coordinate and run the experiments. First, the pretest of state anxiety was performed. The experimental group then received the manipulation of anxiety induction and the posttest of state anxiety, whereas the control group did not. Both groups then finished the dot-probe task, which included 64 trials. See Fig. 1a for an illustration of the procedure. Finally, all participants were provided with a relaxing video, which was included in all the experiments.

Anxiety induction Anxiety was experimentally induced by the procedure used by Montorio and his colleagues (Montorio et al., 2015). This procedure included reading 25 sentences concerning relevant anxious thoughts, at the speed of one every 12 s for 5 min (Velten, 1968), and then experiencing a 2-min period of mood incubation, with the goal of making them feel as anxious as possible. During this time, a piece of anxiety-arousing music (Ligeti Project, “Requiem”) was played. Detailed information regarding the 25 anxious Velten sentences is presented in the [supplementary materials](#).

Measure of anxiety The Visual Analogue Mood Scale (VAMS; McCormack, Horne, & Sheather, 1988) was adopted to measure state anxiety. Participants were asked to rate their current subjective experience of anxiety on a bar, with 0 at one end and 100 at the other.

Dot-probe task The dot-probe task was used to detect attentional biases (MacLeod, Mathews, & Tata, 1986). Example trial sequences are presented in Fig. 2. In each trial, a fixation “+” appeared at the center of the screen for 500 ms and was then replaced by a word pair for another 500 ms. Each word pair consisted of a negative word and a neutral word, which were presented in the left and right parts of the screen. After a 50-ms interval, a probe “*” appeared at the location of one of the words, and participants were instructed to indicate the location (left or right) as soon as possible. The next trial started 1,000 ms after participants responded, or after 2,000 ms without a response. The locations of the words and the probe were randomized and counterbalanced. The congruent condition was defined when the negative word and the probe appeared in the same location, whereas an incongruent trial meant that the negative word and probe were presented in different locations. The attentional bias index was thus calculated by subtracting the average reaction time (RT) of congruent trials from that of incongruent trials. A positive score implied attention toward the negative stimuli, whereas a negative score indicated attention away from the negative stimuli (Shechner et al., 2012).

Word stimulus A set of 96 words (48 negative and 48 neutral words) was used as the stimuli in the dot-probe

¹ All the experiments reported in this article received approval from the Psychology Research Ethics Committee of Tsinghua University (Permit No. 20160907).

² In the initial design, we also attempted to differentiate and measure trait anxiety (high and low) by means of the Trait Anxiety Scale (Spielberger, 1971), which led to a doubling of the sample size. However, considering the integrity and rationality of the theoretical framework, we do not report the results for trait anxiety in the present article. Using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007), we determined that the present sample size was sufficient to obtain an adequate power of $1 - \beta > .83$ to detect a medium-sized effect $f = 0.15$ ($\alpha = .05$).

Fig. 1 Procedures of the four experiments

task. A total of 67 students (34 males, 33 females; $M_{\text{age}} = 21.22$ years, $SD = 2.84$) from a psychology class who were not involved in any other experiments in the present study rated the emotional valence and frequency of these words on a 7-point scale (from 1 = *very negative* to 7 = *very positive*, or 1 = *very rare* to 7 = *very frequent*). Paired-samples t tests revealed significant differences in emotional valence between the negative words and the neutral words [$t(47) = -32.620$, $p < .001$, $d = 4.709$], but not differences in word frequency [$t(47) = 0.864$, $p = .392$, $d = 0.125$]. Detailed information regarding these words is shown in the [supplementary materials](#).

Results

The independent-samples t test showed no differences between the experimental and control groups in trait anxiety levels ($M_{\text{exp}} = 64.50$, $SD_{\text{exp}} = 25.21$, $M_{\text{con}} = 67.27$, $SD_{\text{con}} = 24.00$) [$t(95) = -0.553$, $p = .581$, $d = 0.112$] or in state anxiety during the pretest ($M_{\text{exp}} = 28.44$, $SD_{\text{exp}} = 24.16$, $M_{\text{con}} = 33.14$, $SD_{\text{con}} = 25.92$) [$t(95) = -0.924$, $p = .358$, $d = 0.188$]; however, the anxiety-induced group increased significantly in state anxiety at posttest ($M_{\text{pre}} = 28.44$, $SD_{\text{pre}} = 24.16$, $M_{\text{post}} = 58.04$, $SD_{\text{post}} = 23.90$) [$t(47) = -8.738$, $p < .001$, $d = 1.261$]. These results demonstrated the successful manipulation of anxiety induction.

Fig. 2 Example trial sequences in the dot-probe task

Fig. 3 Reaction times (in milliseconds) in the dot-probe task for the anxiety-induced group and the control group. Unless otherwise stated, error bars represent standard errors of the means

We excluded 0.74% of trials overall. The attentional bias index of the two groups was calculated and revealed a significant difference [$t(95) = 2.654, p = .009, d = 0.538$], with the anxiety-induced group having significantly higher scores ($M = 6.56, SD = 17.77$) than the control group ($M = -1.78, SD = 12.84$). The paired-sample t tests showed that for the anxiety-induced group, the mean RT for neutral words was higher than that for negative words ($M_{\text{neut}} = 388.89, SD_{\text{neut}} = 87.55; M_{\text{neg}} = 382.34, SD_{\text{neg}} = 81.07$) [$t(47) = 2.557, p = .014, d = 0.372$], whereas no significant difference was found in the control group ($M_{\text{neut}} = 364.66, SD_{\text{neut}} = 70.81; M_{\text{neg}} = 366.44, SD_{\text{neg}} = 74.23$) [$t(48) = -0.973, p = .336, d = 0.137$], as is shown in Fig. 3. The results of Experiment 1 suggest that induced state anxiety increases attentional bias toward negative stimuli; thus, our first hypothesis (H1) was supported.

Experiment 2

In Experiment 2, we adopted the attentional bias modification (ABM) procedure developed by MacLeod et al. (2002) to manipulate attentional bias, to explore the influence of attentional bias on state anxiety under stressful conditions. The hypothesis to be examined was that a negative attentional bias increases state anxiety under stressful conditions (H2).

Method

Participants

A total of 56 university students were recruited to participate in Experiment 2. One student was excluded due to a high rate (exceeding 10%) of wrong responses, resulting in 55 valid participants (26 males, 29 females; $M_{\text{age}} = 20.73$ years, $SD = 2.05$), which was still consistent with the sample size suggested by G*Power 3.1 (Faul,

Erdfelder, Lang, & Buchner, 2007).³ Participants were randomly assigned to the experimental group ($N = 28$) or the control group ($N = 27$).

Procedure and materials

All participants completed the TAI online when they were recruited. When they arrived for the session, the pretest of state anxiety was performed. The ABM training was then applied, in which the experimental group and the control group received different manipulations in the training phase. After that, all participants finished the midtest of state anxiety, the stress task, and the posttest of state anxiety. See Fig. 1b for a better illustration of the procedure.

ABM training This training has been widely used in previous studies for attention training (Bar-Haim, 2010; MacLeod & Mathews, 2012; MacLeod et al., 2002). The ABM procedure involved three phases. Phase 1 and Phase 3 were a pretest and a posttest of attentional bias, respectively, for which we adopted the traditional dot-probe task described in Experiment 1. Phase 2 consisted of the training, in which the participants in the experimental group were deliberately trained to modify their attention toward the negative stimuli; the participants in the control group were trained to modify their attention toward the neutral stimuli. In the original dot-probe task, the probe replaces the negative or neutral words at random, with a 50:50 chance. However, in the modified dot-probe task used in ABM training, the probes always replaced the negative words in the experimental group and the neutral words in the control group (Fox, Zougkou, Ridgewell, & Garner, 2011). Phases 1 and 3 involved 64 trials each, and Phase 2 involved 384 trials in six blocks.

³ Using G*Power 3.1 (Faul et al., 2007), we determined that the present sample size was sufficient to obtain an adequate power of $1 - \beta > .80$ to detect a medium-sized effect $f = 0.20$ ($\alpha = .05$).

Word stimuli Two sets of 32 word pairs (32 negative words and 32 neutral words in each set) were used as the stimuli in the ABM training. The first word set was used in Phases 1 and 2, whereas the second set was used in Phase 3. These words had been rated by the same participants as those in Experiment 1. Paired-sample *t* tests revealed significant differences in emotional valence between the negative words and the neutral words in the first word set [$t(31) = -34.488, p < .001, d = 6.096$] and in the second word set [$t(31) = -35.113, p < .001, d = 6.207$]. Meanwhile, no significant difference was found in word frequency in either the first word set [$t(31) = 0.174, p = .863, d = 0.031$] or the second word set [$t(31) = 0.089, p = .929, d = 0.016$]. See the [supplementary materials](#) for more information.

Stress task Mental arithmetic was used as a stress task. Participants were asked to complete ten mental calculation problems within 30 s each. All the problems involved two-digit multiplication, such as 75×42 .

Measure of anxiety State anxiety was measured by the VAMS (McCormack et al., 1988) three times during the process. The pretest was administered at the very beginning, to establish the baseline; the midtest was conducted after the ABM training but before the stress task; and the posttest was completed after the stress task. The anxiety variances were introduced in order to exclude the impact of the baseline level of state anxiety and ensure that state anxiety had been generated by the experimental task. Before the stress task was presented, the anxiety variances were calculated by subtracting the pretest from the midtest VAMS scores. After the stress task, the anxiety variances were calculated by subtracting the pretest from the posttest VAMS scores.

Results

According to the suggestions of Mogg, Wilson, Hayward, Cunning, and Bradley (2012), error trials and

trials with an RT of less than 200 ms or more than 1,200 ms should be removed. After eliminating the 1.46% of trials that were invalid, we examined the effect of ABM training on the basis of the attentional bias indexes before and after the modification. A 2 (ABM training: negative vs. control) $\times$ 2 (test time: pretest vs. posttest) repeated measures analysis of variance (ANOVA) was thus conducted, with attentional bias index as the dependent variable. No main effects were shown for ABM training [$F(1, 53) = 2.746, p = .103, \eta^2 = .049$] or test time [$F(1, 53) = 0.500, p = .483, \eta^2 = .009$]. However, a significant ABM Training $\times$ Test Time interaction was observed [$F(1, 53) = 8.224, p = .006, \eta^2 = .134$]. Specifically, paired-samples *t* tests showed that for the experimental group, with the negative ABM, the mean RT for neutral words was higher than that for negative words on the posttest [$t(27) = 2.772, p = .010, d = 0.524$], whereas no significant difference had been found in the pretest [$t(27) = 1.371, p = .182, d = 0.260$]. There were no significant differences in the comparisons within the control group ($ps > .05$). See Fig. 4 for a better illustration of these results. These results demonstrated the training effect of ABM, showing that the experimental group was successfully manipulated to generate an attentional bias toward the negative stimuli.

We further investigated how the ABM and the stress task influenced changes in state anxiety levels. A 2 (ABM training: negative vs. control) $\times$ 2 (stress task: before vs. after) repeated measures ANOVA was conducted with anxiety variances as the dependent variable. ABM training had no main effect on anxiety [$F(1, 53) = 1.250, p = .269, \eta^2 = .023$], whereas the stress task showed a significant effect [$F(1, 53) = 48.002, p < .001, \eta^2 = .475$]. A significant ABM Training $\times$ Stress Task interaction effect on anxiety [$F(1, 53) = 6.196, p = .016, \eta^2 = .105$] was found, as is shown in Fig. 5. Before the stress task was conducted, the ABM training had no impact on anxiety change ($M_{\text{exp}} = 11.25, SD_{\text{exp}} = 22.91, M_{\text{con}} = 12.04, SD_{\text{con}} =$

Fig. 4 Training effect of the ABM procedure

Fig. 5 Anxiety variance before and after the stress task in the negative ABM group and the control group

17.61) [$t(53) = -0.142, p = .887, d = 0.039$]. However, after the stress task, the anxiety variances of the experimental group ($M = 35.61, SD = 22.14$) were significantly higher than those of the control group ($M = 23.52, SD = 21.02$) [$t(53) = 2.075, p = .043, d = 0.560$]. Thus, although both groups' state anxiety levels increased after the stress task, participants with negative ABM training showed a greater increase. These results suggest that attentional bias itself cannot lead to anxiety, but a stress stimulus is necessary to allow attentional bias to influence the occurrence of anxiety. This finding is consistent with a previous study (MacLeod et al., 2002) and supports H2, that negative attentional bias increases state anxiety under stressful conditions.

Furthermore, to rule out the possible effects of trait anxiety and baseline state anxiety, independent-samples t tests were conducted, revealing no differences between the two groups in trait anxiety ($M_{\text{exp}} = 67.96, SD_{\text{exp}} = 10.72; M_{\text{con}} = 70.93, SD_{\text{con}} = 17.04$) [$t(53) = -0.775, p = .442, d = 0.208$] or in baseline state anxiety ($M_{\text{exp}} = 31.43, SD_{\text{exp}} = 23.68; M_{\text{con}} = 29.26, SD_{\text{con}} = 22.73$) [$t(53) = 0.346, p = .730, d = 0.093$].

Experiment 3

Experiment 3 was conducted to investigate the moderating effect of cognitive appraisal on the influence of state anxiety on attentional bias, on the basis of Experiment 1. State anxiety was rigorously manipulated as an anxious state (high-anxiety-induced) or a calm state (low-anxiety-induced) by a standardized induction procedure (Montorio et al., 2015). Cognitive appraisal was measured according to Folkman's definition (Folkman, Lazarus, Dunkel-Schetter, et al., 1986; Folkman, Lazarus, Gruen, & Delongis, 1986). The hypothesis to be examined was that cognitive appraisal moderates the relationship between state anxiety and attentional bias (H3).

Method

Participants

A total of 144 university students were recruited to participate in Experiment 3. One was excluded due to a high rate (exceeding 10%) of wrong responses, which was still consistent with the sample size suggested by G*Power 3.1 (Faul et al., 2007).⁴ The remaining participants (67 males, 76 females, $M_{\text{age}} = 21.36, SD = 2.59$) were randomly assigned to the high-anxiety-induced group ($N = 71$) or the low-anxiety-induced group ($N = 72$).

Procedure and materials

All participants completed the TAI online when they were recruited. The pretest of state anxiety was conducted after they arrived at the psychology laboratory. Both groups then received the manipulation of anxiety induction and the posttest of state anxiety. Next they completed the dot-probe task and the cognitive appraisal procedure. Finally, the cognitive appraisal was conducted, as is shown in Fig. 1c.

The measurement of anxiety, the dot-probe task, and the word stimuli were identical to those used in Experiment 1. However, both groups in Experiment 3 went through the induction process, to achieve a more rigorous manipulation of state anxiety. The high-anxiety-induced group went through the same procedure as in Experiment 1. The low-anxiety-induced group read another 25 sentences with relevant calm thoughts, at the speed of one every 12 s for 5 min (Velten, 1968); experienced a 2-min period of mood incubation, with

⁴ As in Experiment 1, in Experiment 3 we initially differentiated and measured trait anxiety (high and low), which was not associated with the theoretical framework of the present study and thus was removed from the present article. Using G*Power 3.1 (Faul et al., 2007), we determined that the present sample size was sufficient to obtain an adequate power of $1 - \beta > .85$ to detect a medium-sized effect of $f = 0.15$ ($\alpha = .05$).

Fig. 6 Effect of anxiety induction in Experiment 3

the goal of leaving them feeling as calm as possible; and listened to a piece of Arnold Schoenberg, “Erwartung” (Montorio et al., 2015), for 7 min. Detailed information regarding the 25 calm Velten sentences is shown in the [supplementary materials](#).

Cognitive appraisal We referred to Folkman’s definition and measurement of cognitive appraisal and asked participants to evaluate whether anxiety influenced their wellbeing and physical health (Folkman, Lazarus, Dunkel-Schetter, et al., 1986; Folkman, Lazarus, Gruen, & Delongis, 1986). The appraisal was assessed via a self-report measure with a rating from 0 to 100 (0 for *no influence at all* and 100 for *the greatest influence*). The questions were “To what extent do you believe anxiety can be harmful to your well-being?” and “To what extent do you believe anxiety can be harmful to your physical health?”

Results

Experiment 3 replicated and verified the main findings in Experiment 1. The groups exhibited no differences in levels of trait anxiety and state anxiety on the pretest ($ps > .05$). The anxiety induction procedure was also successful. The high-anxiety-induced group increased significantly in the posttest of state anxiety [$t(70) = 7.797$, $p < .001$, $d = 0.925$], whereas the low-anxiety-induced group declined significantly [$t(71) = -5.263$, $p < .001$, $d = 0.621$]. See Fig. 6 for a better illustration.

After eliminating the 0.73% of data that were invalid, we found a significant difference in the attentional bias indexes in the two groups [$t(141) = 3.038$, $p = .003$, $d = 0.508$]. The high-anxiety-induced group had much higher scores ($M = 6.37$, $SD = 14.16$) than did the low-anxiety-induced group ($M = -0.37$, $SD = 12.31$). A paired-samples t tests showed that for the high-anxiety-induced group, the mean RT for neutral words was higher than that for negative words ($M_{\text{neut}} = 378.19$, $SD_{\text{neut}} = 51.65$; $M_{\text{neg}} = 371.82$, $SD_{\text{neg}} = 50.29$) [$t(70) = 3.791$, $p < .001$, $d = 0.451$], whereas no significant difference was found in the low-anxiety-induced group ($M_{\text{neut}} = 376.65$, $SD_{\text{neut}} = 56.75$; $M_{\text{neg}} = 377.02$, $SD_{\text{neg}} = 54.33$) [$t(71) = -0.253$, $p = .801$, $d = 0.030$]. These results suggest that high state anxiety increases the attentional bias toward negative stimuli, further supporting H1.

Table 1 shows descriptive data for the cognitive appraisal and t test results of the two groups in each condition. A significant difference was found in terms of wellbeing, but not in terms of physical health, in the cognitive appraisal.

We further explored the moderating effect of cognitive appraisal on the influence of state anxiety on attentional bias. PROCESS for SPSS (Model 1) was applied (Hayes, 2013; Preacher & Hayes, 2008). We used bootstrap analyses with 5,000 samples, with anxiety induction (high vs. low) as the independent variable (the high-anxiety-induced group was coded $X = 0$, and the low-anxiety-induced group was coded $X = 1$), attentional bias index as the dependent variable, and cognitive appraisal’s effect on each aspect as the moderator. Thus, two moderation analyses were conducted, both of which revealed no significant moderating effect, as is shown

Table 1 Descriptive data for cognitive appraisal and t test results in Experiment 3 ($N = 143$)

Cognitive appraisal	High-anxiety-induced group, M (SD)	Low-anxiety-induced group, M (SD)	t	p	d
Wellbeing	84.77 (12.92)	79.56 (14.66)	2.257	0.026	0.378
Physical health	79.80 (17.10)	75.38 (17.19)	1.125	0.130	0.258

Table 2 Moderating effects of cognitive appraisal ($N = 143$)

Cognitive appraisal	Coeff.	SE	<i>t</i>	<i>p</i>	95% CI
Wellbeing	0.096	0.163	0.587	.558	[− 0.23, 0.42]
Physical health	− 0.014	0.130	− 0.104	.918	[− 0.27, 0.24]

in Table 2. These results suggest that cognitive appraisal does not moderate the influence of state anxiety on attentional bias.

Experiment 4

Experiment 4 was conducted to further explore the results of Experiment 2, in which we examined the moderating effect of cognitive appraisal on the influence of attentional bias on state anxiety. The hypothesis to be examined was also H3, that cognitive appraisal moderates the relationship between state anxiety and attentional bias.

Method

Participants

A total of 77 students were recruited (37 males, 40 females; $M_{\text{age}} = 21.39$ years, $SD = 2.53$).⁵ Participants were randomly assigned to the experimental group, with negative ABM ($N = 38$), or the control group ($N = 39$).

Procedure and materials

As in Experiment 2, participants completed the TAI online when they were recruited. The pretest of state anxiety was conducted after they arrived at the psychology laboratory. The ABM training then was performed. After that, all participants completed the stress task and the posttest of state anxiety. As in Experiment 3, the cognitive appraisal contained questions regarding wellbeing and physical health. See Fig. 1d for a better illustration of the procedure.

Results

Experiment 4 replicated and verified the main findings of Experiment 2. The experimental group, with negative ABM, and the control group exhibited no differences from one another in their levels of trait and state anxiety on the pretest ($ps > .05$). After eliminating the 1.1% of trials that were invalid, we examined the effect of ABM training on the attentional bias index. As in Experiment 1, no main effects were found

in either ABM training or test time ($ps > .05$). However, a significant ABM Training $\times$ Test Time interaction was observed [$F(1, 75) = 5.483$, $p = .022$, $\eta^2 = .068$]. Specifically, a paired-samples t tests showed that for the experimental group, with negative ABM, the mean RT for neutral words was higher than the mean RT for negative words on the posttest ($M_{\text{neut}} = 355.27$, $SD_{\text{neut}} = 52.27$; $M_{\text{neg}} = 348.56$, $SD_{\text{neg}} = 52.73$) [$t(37) = 2.544$, $p = .015$, $d = 0.412$], whereas no significant difference had been found in the pretest ($M_{\text{neut}} = 365.63$, $SD_{\text{neut}} = 57.43$; $M_{\text{neg}} = 363.64$, $SD_{\text{neg}} = 52.68$) [$t(37) = 0.896$, $p = .376$, $d = 0.146$]. There were no significant differences in the comparisons within the control group ($ps > .05$). Thus, the training effect of ABM was shown again. Similarly, we found that the negative-ABM-training group exhibited greater anxiety variance than did the control group under the stressful condition ($M_{\text{exp}} = 36.16$, $SD_{\text{exp}} = 23.58$, $M_{\text{con}} = 25.15$, $SD_{\text{con}} = 20.81$) [$t(75) = 2.173$, $p = .033$, $d = 0.495$], which agreed with Experiment 2. These results suggest that negative attentional bias increases state anxiety under stressful conditions, further supporting H2.

Table 3 shows descriptive data for the cognitive appraisal and t test results of the two groups in each condition. No significant differences were found in any condition ($ps > .05$).

We further explored the moderating role of cognitive appraisal in the effect of attentional bias on state anxiety. We used bootstrap analyses with 5,000 samples (Model 1 in Hayes, 2013; Preacher & Hayes, 2008), with the ABM training (negative vs. control) as the independent variable (the negative ABM training group was coded $X = 0$, and the control group was coded $X = 1$), anxiety variance under the stressful condition as the dependent variable, and cognitive appraisal as the moderator. Thus, two moderation analyses were conducted, and both revealed significant moderating effects. See Tables 4 and 5 for detailed results.

Table 6 shows the moderating effect of cognitive appraisal on wellbeing. The relationship between ABM training and anxiety variance under the stressful condition was moderated by the degree of the cognitive appraisal of wellbeing. In the condition of lower appraisal (the participant believed that anxiety could not be harmful to his or her wellbeing), the relationship between ABM training and anxiety variance under the stressful condition was not significant. However, the connection was established in the condition of higher cognitive appraisal of wellbeing (in which the participant believed that anxiety could be harmful to his or her wellbeing). Similar conclusions could be drawn for the cognitive appraisal of physical health, as shown in Table 7. Overall, we did not find significant differences between the two groups with low cognitive appraisal for anxiety, who believed it could not be harmful to their wellbeing or physical health, but participants with high cognitive appraisal for anxiety, who believed it could be harmful to their wellbeing or physical health, were more elevated in state anxiety in the negative ABM group than in the

⁵ Using G*Power 3.1 (Faul et al., 2007), we determined that the present sample size was sufficient to obtain an adequate power of $1 - \beta > .80$ to detect a medium-sized effect $f = 0.20$ ($\alpha = .05$).

Table 3 Descriptive data for the cognitive appraisal and *t* test results in Experiment 4 (*N* = 77)

Cognitive appraisal	Negative ABM training group, <i>M</i> (<i>SD</i>)	Control group, <i>M</i> (<i>SD</i>)	<i>t</i>	<i>p</i>	<i>d</i>
Wellbeing	76.08 (14.25)	70.26 (18.92)	1.523	.132	0.348
Physical health	73.00 (15.18)	70.64 (12.44)	0.747	.458	0.170

control group. These results revealed a moderating effect of cognitive appraisal on the influence of attentional bias on state anxiety. Taken together, the findings of Experiments 3 and 4 suggest that cognitive appraisal only moderates the influence of attentional bias on state anxiety, rather than vice versa, which partially supports H3.

Discussion

The present study has described the interaction between state anxiety and attentional bias, as well as the moderating effect of cognitive appraisal on the interaction. In Experiment 1, we demonstrated that state anxiety significantly increased attentional bias to negative stimuli. In Experiment 2, we found a significant interaction between the effects of attentional bias and stressful condition on state anxiety. An attentional bias to negative stimuli (and not to neutral stimuli) significantly increased state anxiety under the stressful condition. In Experiment 3, we replicated the results of Experiment 1 but did not find a moderating effect of cognitive appraisal (for either wellbeing or physical health) on the influence of state anxiety on attentional bias. In Experiment 4, we replicated the results of Experiment 2, and further found moderating effects of cognitive appraisal (for both wellbeing and physical health) on the influence of attentional bias on state anxiety under the stressful condition.

In Experiments 1 and 2, we manipulated state anxiety or attentional bias within similar samples and similar designs, to investigate the interaction between state anxiety and attentional bias. In Experiment 1 we recruited healthy university students randomly and induced state anxiety in the laboratory, and thus bypassed the feedback loop between anxiety disorders or trait anxiety and negative attentional bias (Eysenck, 1992, 1997). We found that induced state anxiety could lead to an attentional bias, which provides new evidence for the inconsistent findings of previous studies (Carretié, Mercado, Hinojosa, Martín-Loeches, & Sotillo, 2004; Dennis, Chen,

& McCandliss, 2010; Dresler, Mériaux, Heekeren, & Meer, 2009; Fox, Russo, Bowles, & Dutton, 2001; Peers & Lawrence, 2009). In Experiment 2, we found that attentional bias significantly influenced state anxiety under the stressful condition. This finding is consistent with that of MacLeod et al. (2002). It suggests that attentional bias modification is also effective for Chinese university students. Taken together, the findings of Experiments 1 and 2 suggest that state anxiety and attentional bias truly interact with each other through a positive feedback loop, which has also been described from the previous theoretical perspectives (Bar-Haim et al., 2007; Beck, 1976; Eysenck, 1992; Mathews & MacLeod, 2002; Van Bockstaele et al., 2014; Williams et al., 1997); that is, a higher level of state anxiety directly leads to a negative attentional bias (Exp. 1), and, in turn, individuals with a negative attentional bias experience a significantly higher level of state anxiety under stressful conditions than do those in a control group (Exp. 2). Unlike in the previous studies, we conducted several experiments to test the interaction between state anxiety and attentional bias in the two directions (from state anxiety to attentional bias and vice versa) within similar samples and similar designs, whereas previous research had only considered one of these potential causal directions in isolation using patient samples with anxiety disorders or trait anxiety. We dismantled the feedback loop of clinical anxiety and attentional bias but manipulated state anxiety or attentional bias for the individuals who did not have anxiety disorders or trait anxiety in the laboratory, which could provide direct evidence for the interaction between state anxiety and attentional bias.

Another significant contribution of the present study was its examination of the potential moderating effect of cognitive appraisal when accounting for the interaction between state anxiety and attentional bias. We found that cognitive appraisal moderated the influence of attentional bias on state anxiety under the stressful condition, but not the opposite influence, in Experiments 3 and 4. Therefore, H3 was partially supported. Considering both the findings of the four experiments and

Table 4 Moderation analysis—cognitive appraisal: wellbeing (*N* = 77)

	Coeff.	<i>SE</i>	<i>t</i>	<i>p</i>	95% CI
Constant	− 34.672	18.078	− 1.918	.059	[− 70.70, 1.36]
Cognitive appraisal: Wellbeing	0.931	0.234	3.984	.000	[0.47, 1.40]
ABM training	74.197	22.050	3.365	.001	[30.25, 118.14]
Interaction	− 1.136	0.291	− 3.900	.000	[− 1.72, − 0.56]

Table 5 Moderation analysis—cognitive appraisal: physical health ($N = 77$)

	Coeff.	SE	<i>t</i>	<i>p</i>	95% CI
Constant	− 25.401	16.599	− 1.530	.130	[− 58.48, 7.68]
Cognitive appraisal: Physical health	0.843	0.228	3.786	.000	[0.40, 1.29]
ABM training	42.132	25.401	1.659	.102	[− 8.49, 92.76]
Interaction	− 0.724	0.349	− 2.077	.041	[− 1.42, − 0.03]

Table 6 Moderating effect of cognitive appraisal: wellbeing ($N = 77$)

Cognitive appraisal		Effect	<i>SE</i>	<i>t</i>	<i>p</i>	95% CI
Wellbeing						
<i>M</i> − 1 <i>SD</i>	56.209	10.369	6.987	1.484	.142	[− 3.56, 24.29]
<i>M</i>	73.1309	− 8.846	4.694	− 1.885	.064	[− 18.20, 0.51]
<i>M</i> + 1 <i>SD</i>	90.051	− 28.061	6.617	− 4.241	.000	[− 41.25, − 14.87]

previous theoretical perspectives (Bar-Haim et al., 2007; Beck, 1976; Eysenck, 1992; Mathews & MacLeod, 2002; Van Bockstaele et al., 2014; Williams et al., 1997), it is reasonable to propose a positive feedback loop between state anxiety and attentional bias, which is moderated by cognitive appraisal; this is shown in Fig. 7. First, the results suggest that attention training can be used to reduce state anxiety, and is thus helpful in relieving state anxiety. At the same time, for individuals with state anxiety, two key factors affect the positive feedback loop of state anxiety and attentional bias: One is stressful conditions, and the other is cognitive appraisal. It is known that most of the objective stressful condition is beyond our control, but cognitive appraisal as an important personal coping resource could regulate the anxiety experience. This finding provides empirical evidence for relieving state anxiety by adjusting cognitive appraisal, which is consistent with rational emotive behavior therapy and cognitive-behavioral therapy (Beck, 1976, 1993; Ellis, 1971).

The results from our work also identify a number of important directions for future research. First, in our experiments, we measured only two kinds of cognitive appraisal: for wellbeing and physical health. In fact, the cognitive appraisal proposed by Folkman et al. includes both primary appraisal and secondary appraisal (Folkman, Lazarus, Dunkel-Schetter, et al., 1986; Folkman, Lazarus, Gruen, & Delongis, 1986).

Table 7 Moderating effect of cognitive appraisal: Physical health ($N = 77$)

Cognitive appraisal	Effect	<i>SE</i>	<i>t</i>	<i>p</i>	95% CI
Physical health					
<i>M</i> − 1 <i>SD</i>	57.987	0.147	6.684	0.022	.983 [− 13.17, 13.47]
<i>M</i>	71.805	− 9.858	4.705	− 2.095	.040 [− 19.24, − 0.48]
<i>M</i> + 1 <i>SD</i>	85.624	− 19.863	6.784	− 2.928	.005 [− 33.38, − 6.34]

Future work should examine the role of other forms of cognitive appraisal in the interaction between state anxiety and attentional bias, to verify the generalizability of the findings in the present study. Second, to dismantle the feedback loop pattern of anxiety disorders or trait anxiety and attentional bias, we recruited research samples from among normal people. The normal people did not suffer from the positive feedback loop of anxiety and attentional bias; hence, it was possible to examine the interaction between (state) anxiety and attentional bias through an experimental manipulation. However, in so doing, we were unable to observe whether cognitive appraisal plays a role in individuals with anxiety disorders or trait anxiety similar to the one it plays in individuals without anxiety disorders or trait anxiety. Future studies should also include individuals with anxiety disorders or trait anxiety, to explore the generalizability of the model shown in Fig. 7.

In conclusion, the present study provides evidence suggesting that the interaction between state anxiety and attentional bias is bidirectional—that is, that state anxiety increases attentional bias, and vice versa. However, cognitive appraisal only moderates the influence of attentional bias on state anxiety,

Fig. 7 Unidirectional moderating effect of cognitive appraisal in the interaction between state anxiety and attentional bias

rather than the reverse. There are two implications of our findings: First, we provided empirical evidence of the interaction between state anxiety and attentional bias through our experimental manipulations; second, we offer insight into the moderating effect of cognitive appraisal on the influence of attentional bias on state anxiety, but not on the reverse influence, which provides direct evidence for relieving state anxiety by adjusting cognitive appraisal.

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