The Impact of Mindfulness Training on the Attention to Facial Expressions

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Abstract

The improvements of attention by mindfulness training had been proved. But the effects of mindfulness training on attention to emotional stimuli were mixed. We employed a randomized, controlled design to investigate the effects of mindfulness training on the attention to emotional expressions, and investigated whether baseline levels of dispositional mindfulness and emotional intelligence would moderate the intervention effects. Forty participants received 8-week mindfulness training and another forty participants attended two lectures about mindfulness. All participants completed the visual search task, the Five Facet Mindfulness Questionnaire, and the Emotional Intelligence Scale at both pre-training and post-training. The improvements of search efficiencies were larger in the mindfulness group than those in the control group for sad and angry faces, but not for happy faces ($F(2, 156)=4.04$, $p=0.019$, $\eta^2=0.05$). In addition, baseline emotional intelligence ($\beta_{sadness}=-4.49$, $t=-2.08$, $p=0.041$, 95%CI [-8.78, -0.19]; $\beta_{anger}=-7.39$, $t=-4.08$, $p<0.001$, 95%CI [-10.99, -3.78]) but not dispositional mindfulness ($\beta_{sadness}=3.17$, $t=1.56$, $p=0.124$, 95%CI [-0.89, 7.22]; $\beta_{anger}=-1.89$, $t=-1.02$, $p=0.313$, 95%CI [-5.61, 1.82]) played a significantly moderating role in the relationship between mindfulness training and emotional attention to sadness and anger. The search efficiencies of negative emotions (i.e., anger and sadness) but not positive emotions (i.e., happiness) were significantly improved by mindfulness training. Individuals with high level of baseline emotional intelligence showed significant improvement on the search efficiencies relative to those with low level of emotional intelligence.

Introduction

Mindfulness is that one consciously brings his/her awareness and attention to the present inner and external experiences in a curiosity, openness/receptiveness, and non-judgemental way [1,2]. Mindfulness skills can be improved by a series of scientific and standardized techniques, leading individuals to achieve a highly aware, balanced and relaxed state of mindfulness and to break the automatic reaction pattern for stimuli-actions. Evidence has shown that mindfulness training can decrease one's psychological and physical problems [3–5]. Clinically, it has been used as a treatment of emotional disorders such as anxiety and depression [6–9].

The core of mindfulness is an intentional, non-critical form of attention that focuses on present experiences without being involved in the rumination for past experiences and anticipating the future [10]. Therefore, higher level of mindfulness might be associated with better attention. Previous studies revealed that self-reported mindfulness was positively correlated with the attentional performance in a Stroop interference task [11] and the sustained attention in the Continuous Performance Test II [12]. Neuroimaging evidence also showed that trait mindfulness was associated with activations in attentional network such as parietal cortex [13]. Training on mindfulness has been found to improve the attentional processing. For example, mindfulness-based cognitive therapy (MBCT) may enhance sustained attention [14]; meditation was correlated with more accurate, efficient, and flexible visual attentional processing [15];

and individuals who received mindfulness-based stress reduction (MBSR) training showed significant improvements in a variety of attentional tasks [16–22] [15].

One of the main purposes and consequences of mindfulness training is improving emotional regulation and releasing emotional disorders. Evidence has shown that mindfulness can modulate emotional processing, which might be an important mechanism underlying emotional regulation enhancement. First, highly trait mindfulness was found to be associated with faster response time and more negative N100 and N200 amplitudes to emotional facial expressions in an emotional Go/NoGo task, indicating a higher sensitivity to emotional stimuli among these individuals [23]. Second, mindfulness training was found to improve emotional processing [24,25]. For examples, it reduced emotional interference from unpleasant pictures [26] and decreased perceived emotional intensity in response to both positive and negative emotional stimuli [27,28]. Correspondingly, electrophysiological evidence indicated that mindfulness training attenuated N170 amplitude during affect matching [29]. Another study showed that mindfulness training attenuated the amplitude of P1 elicited by the negative and neutral stimuli but not positive stimuli [30]. However, it should be also noted that other studies showed that a brief mindfulness induction and the trait mindfulness may have little influence on ERP activities during emotional processing [31,32].

As the core of mindfulness is attentional allocation, it is still in debate whether the mindfulness modulates emotional processing through specific attention to the affective stimuli. On one hand, it is proposed that mindfulness may modulate attentional processing to all kinds of emotional stimuli. For example, in a dot-probe task, mindfulness was associated with shorter reaction times for pleasant, neutral, and unpleasant stimuli [33]. Furthermore, in an affective Stroop task, it was found that mindfulness training improved reaction speed for both the pleasant and unpleasant stimuli [34]. Electrophysiological evidence demonstrated that individuals with high level of dispositional mindfulness showed weaker late positive potential (LPP) responses to both high-arousal unpleasant pictures and motivation-salient pleasant pictures (e.g., erotica) [35]. In addition, mindfulness training could attenuate the amplitude of LPP elicited by positive, negative and neutral stimuli [30]. On the other hand, some researchers proposed that the impact of mindfulness training on emotional attention was modulated by the valence of emotional stimuli. For example, it was found that mindfulness training reduced attentional bias toward negative rather than positive affective stimuli in a dot-probe task [28]. Similarly, in an emotional interference task, mindfulness training was found to improve the ability to disengage from unpleasant stimuli [26]. Correspondingly, electrophysiological evidence showed that a brief mindfulness induction reduced P300, a component reflecting attentional allocation, in responses to negative pictures [31]. In a neuroimaging study, mindfulness training was found to increase activity in dorsal anterior cingulate cortex, medial prefrontal cortex, and right anterior insula during the processing of negative stimuli in an affective Stroop task [36]. Besides the debate on the impact of emotional valence, there are also studies showing that mindfulness may have little influence on the P3b amplitude to emotional stimuli, indicating small effect of mindfulness on emotional attention [37].

The visual search task is an important paradigm used to study visual spatial attention. In this task, observers are asked to detect a target among an array of distractors as rapidly as possible. The number of distractors is manipulated, and the slope of the function that reaction time (RT) over the set size is proposed as the index of search efficiency which reflects the automatic attentional processing on the target stimulus [38–42]. A shallower slope denotes more automatic attentional bias to the target, and thus little effort may be taken to detect the stimulus. Visual search studies have revealed an anger superiority effect [43,44] and a happy superiority effect [45,46] on the emotional face stimuli. Mindfulness training was found to improve the search efficiency to simple stimuli among adults and children [47,48]. However, little is known about the impact of mindfulness training on the search efficiency to emotional faces. Therefore, in the present study, we aimed to explore the impact of mindfulness training on the attentional processing of facial expressions including happiness, sadness and anger by adopting a visual search task.

Based on previous theories, the impact of mindfulness on emotional processing might be modulated by some factors such as emotional intelligence. Emotional intelligence is defined as the ability to perceive, integrate, understand and regulate emotions in self and in others [49]. Davies, et al. [50] further conceptualized four facets of emotional intelligence: appraisal and expression of emotion in self, appraisal and recognition of emotion in others, regulation of emotion in self, and use of emotion to promote performance. Mindfulness required individuals to observe, understand and accept their own as well as other's feelings in an objective, non-judgmental, non-reactive way, which is very close to the core of emotional intelligence. Studies revealed that the level of dispositional mindfulness was positively correlated with emotional intelligence [51–54]. Furthermore, mindfulness training had positive effect on emotional intelligence [55–57]. It is thus reasonable to assume that individuals with high emotional intelligence may be more easily to achieve the state of mindfulness. In other words, mindfulness training may be effective among high emotional intelligence individuals at the first place. Studies also showed that emotional intelligence was associated with emotional recognition [58–61] and sustained attention to emotional stimuli [62]. Therefore, we hypothesized that the effect of mindfulness training on emotional processing might be modulated by emotional intelligence. Specifically, individuals with high emotional intelligence may be more sensitive to mindfulness training, and thus may show larger improvement on emotional attention.

Methods

Participants. In order to find a higher training effect in the mindfulness group compared with the control group, we performed a power analysis to determine the sample size through G*Power 3.1.9.7. At a level of effect size d = 0.8 with a statistical power of 0.95, the result showed that a sample of 70 subjects, at least, was required. At last, eighty undergraduates were recruited and were randomly divided into the mindfulness group and the control group. No age difference was found between the mindfulness group (M=19.45, SD=0.96, ranging from 18 to 23) and the control group (M=19.33, SD=1.07, ranging from 18 to 22) ($t(78)$=0.55, p=0.584). No sex difference was noted between the mindfulness group (29 females and 11 males) and the control group (29 females and 11 males). All of the participants were right-handed and

had normal or corrected-to-normal vision and normal color vision, and none of them had a history of neurological or psychiatric illness.

Measurements. The Emotional Intelligence Scale (EIS) was designed by Schutte, et al. [63] to measure the ability to perceive, understand, control, and manage their own and other's emotions. The EIS has 33 items and contains of four subscales, including appraisal of other's emotion (e.g., "Other people find it easy to confide in me"), appraisal and expression of own emotion (e.g., "I know when to speak about my personal problems to others"), regulation of emotion (e.g., "When my mood changes, I see new possibilities"), and utilization of emotion (e.g., "Emotions are one of the things that make my life worth living"). All of the items were rated on a 5-point Likert scale from 1 ("strongly disagree") to 5 ("strongly agree"). The original authors reported a Cronbach's α of 0.90 and a two-week test-retest reliability of 0.78 [63]. The Cronbach's α was 0.86 in a Chinese sample [64].

The Five Facet Mindfulness Questionnaire (FFMQ) was used to measure the mindfulness of participants [65]. It contains 39 items and encompasses five subscales, including observing (e.g., "When I take a shower or bath, I stay alert to the sensations of water on my body"), describing (e.g., "I can easily put my beliefs, opinions, and expectations into words"), acting with awareness (e.g., "When I do things, my mind wanders off and I'm easily distracted"), non-judging (e.g., "I tell myself I shouldn't be feeling the way I'm feeling") and non-reacting (e.g., "When I have distressing thoughts or images, I just notice them and let them go"). All of the items were rated on a 5-point Likert scale from 1 (very rarely true) to 5 (always true). The Cronbach's α of the FFMQ was 0.70 in a Chinese non-clinical sample [66].

Materials. Digital color pictures depicting emotional faces were adopted from the Chinese Facial Affective Picture System (CFAPS) [67]. 16 angry faces, 16 sad faces, 16 happy faces, and 58 neutral emotional faces were selected from the system. All pictures had a uniform size (185*200 pixels) and were matched for brightness and contrast. A repeated measures ANOVA revealed that the emotional valence was significantly different among angry (M=2.62, SD=0.40), happy (M=6.75, SD=0.51), and sad (M=2.84, SD=0.54) faces ($F(2, 30)=351.92$, $p<0.001$, $\eta^2=0.959$), while the arousal was not significantly different among angry (M=6.44, SD=1.47), happy (M=5.71, SD=1.12), and sad (M=5.67, SD=1.37) faces ($F(2, 30)=1.60$, $p=0.219$, $\eta^2=0.096$). The valence of neutral faces was moderate (M=4.40, SD=0.37) and the arousal of them was low (M=3.78, SD=0.69).

Apparatus. The visual stimuli were presented on a SAMSUNG 19-in LCD screen, with a spatial resolution of 1,280 × 800 and a refresh rate of 60 Hz [68]. The subjects viewed the stimuli from a distance of 60 cm. The presentation of stimuli was controlled by E-Prime 2.0 software (https://www.pstnet.com). Data analysis was conducted via SPSS 16.0 (https://www.ibm.com/analytics/SPSS-statistics-software).

Procedure. All participants first completed the scales and were then tested with a visual search task in a quiet room. At the beginning of each trial, a white fixation cross was presented in the center of the black screen for a random period of 500~1500 ms. Then, an array of 8 faces (high perceptual load condition) or 2 faces (low perceptual load condition) appeared until a response was made. Participants were asked

to press one key (F) if they found the target (emotional facial expressions) among the distractors (neutral facial expression) and another key (J) if they didn't find the target as quickly and accurately as possible. After the response, a blank screen was presented for 500 ms and then the next trial began. In total, the experiment included 6 blocks and 384 trials. In each block, the perceptual load and the target emotion were fixed. As a result, each block was assigned to one of the six condition (2 load (high/low) × 3 emotion (angry/sad/happy)). Each block contained 64 trials: in 48 trials the target was presented and in 16 trials there was no target. Trial types and the locations of the target were randomly presented in a block, and the block types were counterbalanced among participants. An example of the procedure is demonstrated in Figure 1.

After the baseline measurement, participants were randomly divided into the mindfulness group that received mindfulness training or the control group that attended two lectures about mindfulness. Participants in the mindfulness group had systematically participated in the eight-week course of mindfulness-based stress reduction (MBSR) under the guidance of a therapist who had three years of experience in leading MBSR courses and long-term meditation practice. The mindfulness training program was designed based on the MBSR developed by Kabat-Zinn [10] and the mindfulness-based cognitive therapy (MBCT) [69]. In each weak, participants received a two-hour training course. The contents of weekly training are shown in Table 1. After the training, participants were asked to complete daily mindfulness practice at home and report their feelings.

After the training, participants in the mindfulness group were asked to complete the post-training measurement that was totally the same as the baseline measurement, i.e., the two scales and the visual search task. At the same time, control group also completed the measurement. After all the measurements were completed, the control group also received the mindfulness training if they volunteered to participant.

Statistical analysis. First, as we focused on the effect of mindfulness training, the scale scores and behavioral performance before training were thus treated as baselines and were subtracted from the indicators after training. Such a manipulation could also largely reduced the complexity of our analysis and make our results more clearly to present. Therefore, the following analyses were all based on the improvements of the indicators. Specifically, the improvement of an indicator was calculated as the post-training indicator minus the pre-training indicator. Afterwards, we compared the improvements of scale cores between the two groups with independent-sample t-tests. Then, 2 (Group: mindfulness group / control group) ×3 (Facial emotion: sad / angry / happy) ×2 (Perceptual load: high / low) mixed ANOVAs were conducted on the improvements of accuracy and reaction time (RT) in the visual search task. Next, search slopes for each emotion were calculated as $(RT_{High\ load}-RT_{Low\ load})/(Set\ size_{High\ load}-Set\ size_{Low\ load})$ [40]. The set sizes were 8 and 2 for high load condition and low load condition respectively. The slope is an indicator of search efficiency, i.e., a smaller slope indicates more efficient target search, and the target could draw attention more automatically. A 2 (Group: the mindfulness group / the control group) ×

3 (Facial emotion: sad / angry / happy) mixed ANOVA was then conducted on the improvements of search slopes.

In order to examine the role of emotional intelligence and dispositional mindfulness in moderating the effect of mindfulness training on the attentional processing, we constructed moderation models. In these models, mindfulness training (1=trained; 0=untrained) was set as the independent variable and the improvements of the slopes were set as the dependent variables, and the baseline assessment of emotional intelligence or dispositional mindfulness was set as the moderating variable (for similar reports please see [70-76]. SPSS Macro of PROCESS 3.4.1 provided by Preacher and Hayes [77] was used to test the moderation effects. Once a significant interaction was found, simple slopes were then calculated at low (− 1 SD), average and high (+ 1 SD) values of the moderator, and regions of significance were computed using the Johnson-Neyman technique, which identifies the points on a continuous moderator at which the relationship between the dependent and independent variables is statistically significant [78,79].

Results

Questionnaire results

The improvements of scale scores were demonstrated in Figure 2. Independent sample t-tests revealed significantly larger improvements of dispositional mindfulness ($t(78)=2.31$, $p=0.023$, Cohen's d=0.52) and emotional intelligence ($t(78)=2.28$, $p=0.026$, Cohen's d=0.52) for mindfulness group compared with control group. The results indicated that the mindfulness training successfully improved the dispositional mindfulness of participants, and the emotional intelligence was enhanced at the same time. Regarding the scores of the subscales, compared with controls, mindfulness group showed higher improvements on the subscales of acting with awareness ($t(78)=2.27$, $p=0.026$, Cohen's d=0.51) and non-judging ($t(78)=4.66$, $p<0.001$, Cohen's d=1.04). Other between-group differences for the subscales of emotional intelligence and dispositional mindfulness were not significant (all $t(78)<1.66$, $p>0.10$). The original scores of scales were presented in Table S1.

Visual search task results

Accuracy A 2 (Group: the mindfulness group / the control group) ×3 (Facial emotion: sad / angry / happy) ×2 (Perceptual load: high vs. low) mixed ANOVA for the improvements of accuracy revealed nonsignificant interaction effects and main effects (all $Fs<1.9$, $ps>0.16$). Detailed accuracies were presented in Table S2.

RTs A similar 2 ×3 ×2 mixed ANOVA was performed on the improvements of RTs. As Figure 3 demonstrated, results revealed that the interaction effect of Group× Perceptual load× Facial emotion was significant ($F(2, 156)=4.04$, $p=0.019$, $\eta^2=0.05$). A simple effect analysis indicated that there were no significant between-group differences when the perceptual load was low (all $ps>0.17$), while in the high load condition, the mindfulness group showed larger improvements for angry ($p=0.010$) and sad faces

(p=0.005) than the control group. Additionally, in the mindfulness group, the improvement of happy faces were less than those of sad faces (p=0.027) and angry faces (p=0.001) when the perceptual load was low, while the control group only showed less improvement of happy faces than that of angry faces (p=0.037). Similarly, when the perceptual load was high, the mindfulness group showed less improvement of happy faces were less than those of sad faces (p=0.003) and angry faces (p=0.013), while the trend was not significant in control group. These results suggested that mindfulness training improved target-searching speed for sad and angry targets, but not for happy targets.

Next, the interaction effects of Group × Facial emotion ($F(2, 156)=5.86$, $p=0.004$, $\eta^2=0.07$) and Group × Perceptual load ($F(1, 78)=6.23$, $p=0.015$, $\eta^2=0.07$) were significant, while the interaction effect of Facial emotion× Perceptual load was nonsignificant ($F(2, 156)=2.34$, $p=0.100$, $\eta^2=0.03$). The main effects of Perceptual load ($F(1, 78)=7.75$, $p=0.007$, $\eta^2=0.09$), Facial emotions ($F(2, 156)=5.22$, $p=0.006$, $\eta^2=0.06$), and Group ($F(1, 78)=6.26$, $p=0.014$, $\eta^2=0.07$) were all significant. Detailed RTs were presented in Table S3.

Search slopes A 2 (Group: the mindfulness group / the control group) ×3 (Facial emotion: sad / angry / happy) mixed ANOVA was performed on the improvements of search slopes. As Figure 4 illustrated, a significant interaction effect of Group × Facial emotion ($F(2, 156)=4.04$, $p=0.019$, $\eta^2=0.05$) was found. A simple effect analysis suggested that the improvements were larger in the mindfulness group than those in the control group for sad (p=0.034) and angry (p=0.014) faces, but not for happy faces (p=0.340). Additionally, the mindfulness group showed larger improvement of sad faces than happy faces (p=0.014), while the control group showed larger improvement of happy faces than angry faces (p=0.026). These results indicated that mindfulness training enhanced the searching efficiency for sad and angry target faces.

The main effect of Group was significant ($F(1, 78)=6.23$, $p=0.015$, $\eta^2=0.07$), while the main effect of Facial emotion was nonsignificant ($F(2, 156)=2.34$, $p=0.100$, $\eta^2=0.03$). Detailed slopes were presented in Table S4.

The moderation models

As mindfulness training was found to successfully improve the search efficiency for sad and angry faces, we further examined whether emotional intelligence and dispositional mindfulness could moderate these training effects. First, moderation models for emotional intelligence were constructed, in which the mindfulness training (mindfulness group was assigned to 1, control group was assigned to 0) and the improvements of search slopes (as the search slope is the best indicator of search efficiency and sensitivity for emotional faces) were set as the independent variable and dependent variables respectively, while the emotional intelligence at the baseline measurement [80] was set as the moderating variable. Results showed that the interaction effect of Mindfulness training × Emotional intelligence at baseline could predict the improvements of search slopes for sad faces (β=-0.46, t=-2.08, p=0.041, 95%CI [-8.78, -0.19]) and angry faces (β=-0.85, t=-4.08, p<0.001, 95%CI [-10.99, -3.78]). Simple slope tests

revealed that when the emotional intelligence at baseline was high, mindfulness training could significantly reduce the search slopes for sad faces (β=-0.96, t=-3.11, p=0.003, 95%CI [-188.89, -41.29]) and angry faces (β=-1.41, t=-4.87, p<0.001, 95%CI [-213.47.89, -89.57]), while these effects were nonsignificant when the emotional intelligence at baseline was low (for sad faces: β=-0.04, t=-0.13, p=0.893, 95%CI [-77.30, 67.52]; for angry faces: β=0.28, t=0.98, p=0.329, 95%CI [-30.81, 90.76]) (Figure 5). These results indicated that mindfulness training may be more effective to improve the attentional processing among individuals with high level emotional intelligence.

Similarly, we constructed moderation models in which the dispositional mindfulness at baseline was set as the moderating variable. Results showed that the interaction effect of Mindfulness training × Dispositional mindfulness at baseline could not predict the improvements of search slopes for sad faces (β=0.35, t=1.56, p=0.124, 95%CI [-0.89, 7.22]) and angry faces (β=-0.22, t=-1.02, p=0.313, 95%CI [-5.61, 1.82]).

Discussion

Mindfulness training is shown to be effective in raising one's dispositional mindfulness and emotional intelligence. At the same time, we examined the impact of mindfulness training on the visual attention to emotional faces through a classic visual search paradigm. Results demonstrated that the search efficiencies of negative emotions were significantly enhanced by the training, while little impact was found on the positive emotion. More importantly, emotional intelligence could modulate the training effect, i.e., individuals with high level of emotional intelligence showed a higher improvement on the search efficiencies than those with low level of emotional intelligence. Our results shed light on the mechanisms of mindfulness training.

First, it is not surprising that the mindfulness training could improve the emotional intelligence and dispositional mindfulness, which was consistent with previous studies [55,57,81]. The results on the dispositional mindfulness demonstrated that our training was effective and successfully enhanced participants' ability of mindfulness. The improvement on emotional intelligence indicated that mindfulness and emotional intelligence may share similar mechanisms. Previous studies revealed that the level of mindfulness was positively correlated with emotional intelligence [53,54,82,83]. More specifically, the level of mindfulness could positively predict appraisal and expression of own emotion, regulation of emotion, and utilization of emotion [52,54]. According to the Mindfulness-to-Meaning Theory [84,85], mindfulness allows one to decenter from the appraisals of life events (e.g., emotional information) into a metacognitive state of awareness that improves interoceptive attention to broaden cognitive range, so that the flexibility of reappraisal for life events was enhanced. Such an improvement in reappraisal flexibility for emotional information contributes to reappraising emotions of oneself and others, which further promotes emotional regulation and utilization. Therefore, mindfulness and emotional intelligence may be closely associated with each other.

The core finding of the present study is that mindfulness training could improve the searching efficiencies for emotional faces. These improvements were mainly contributed by shortening the RTs in high load condition and were mainly restricted to negative emotions. These results indicated that mindfulness training effectively improved visual attention to negative rather than positive facial emotions. Critically, the present findings supported our hypothesis that mindfulness training could improve emotional attention. It is not contradictory with previous findings showing reduced emotional responses by mindfulness training, e.g., reduced skin conductance responses to unpleasant pictures [26] and decreased perceived emotion intensity of both positive and negative affective stimuli [27,28]. It should be noted that mindfulness brings attention to emotional stimuli including negative emotions in a curious, receptive, and non-judgemental way. In other words, the mindfulness individuals may actively rather than passively directed their attention to these negative faces and were less readily accessible to negative meanings. As a result, mindfulness might make individuals more willing to direct their attention to both sad and angry faces [86]. Our results were also consistent with previous findings showing that mindfulness training improved attention control for unpleasant rather than pleasant stimuli [26], and increased activations in dorsal anterior cingulate cortex, medial prefrontal cortex, and right anterior insula during the processing of negative stimuli [36]. However, we didn't find a significant improvement in searching efficiency for happy faces. A possible explanation is that the search efficiency for happy faces was already high at the baseline. Among all the participants, the search slope of happy faces ($M = 39.8$, $SD = 45.7$) was significantly smaller than those of sad ($M = 121.2$, $SD = 103.4$) and angry ($M = 94.2$, $SD = 84.7$) faces (all paired $t > 4.9$, $p < 0.001$), demonstrating a happy superiority effect in emotional search [45,46]. As the search efficiency may reach the ceiling of emotional attention, it is thus difficult to be improved anymore. However, we should note that there are also some studies revealed that mindfulness training increased attention to positive stimuli but attenuated attention to negative stimuli [28,30]. Further studies were required to elucidate the training effect on the attentional processing of positive stimuli in specific situations.

Another interesting finding in the present study was that emotional intelligence could moderate the effect of mindfulness training on the search efficiency, consistent with a previous study that emotional intelligence moderated the effect of mindfulness training on stress [80]. Taking the evidence together, it suggests that emotional intelligence may be a prerequisite to be benefit from mindfulness training, and individuals with a higher level of emotional intelligence may be more sensitive to mindfulness training. Based on the theoretical structure of emotional intelligence, individuals with high emotional intelligence may appraise their own and other's emotions more accurately and to regulate their own emotions more effectively. Mindfulness training involves enhancing the awareness of one's emotions, making individuals observe, understand and accept their own and other's emotions in a non-judgmental and non-reactive way [87]. Therefore, an individual with high emotional intelligence may be better at emotional appraisal and emotional regulation and thus easily to achieve the state of mindfulness [51–54]. From this perspective, high emotional intelligence may promote the effect of mindfulness training on the attentional processing of other's emotions.

Finally, our results showed that the dispositional mindfulness could not modulate the effect of mindfulness training on the searching efficiency for emotional faces. One of the reasons might be that the dispositional mindfulness could be changed a lot by mindfulness training, and its untrained state may not indicate one's potential on the sensitivity to the mindfulness training. We further analyzed the scores of FFMQ and found a weak correlation ($r = 0.23$, $p = 0.161$) between the scores before and after training, which supported our inference. Note that the test of FFMQ itself was stable and had a high retest reliability in the control group ($r = 0.47$, $p = 0.002$). Interestingly, emotional intelligence seemed to be a much more stable trait of individuals, as the correlations between the scores before and after training were both high in the mindfulness group ($r = 0.81$, $p < 0.001$) and control group ($r = 0.74$, $p < 0.001$). To sum up, emotional intelligence may be a stable marker that indicates one's sensitivity to mindfulness training, while dispositional mindfulness is likely a state indicator that only reflects one's mindfulness when measured, and has little relationship with the sensitivity to mindfulness training.

Limitations

We noted that there are several limitations in our study. First, we only tested three kinds of emotions including sad, angry and happy, and the stimuli were restricted to faces. Further studies are required to examine other emotions and extend to non-face affective pictures. Second, only emotional intelligence and dispositional mindfulness was examined in the present study. Other moderators or mediators, e.g., empathy, should be tested in further studies. Empathy has been shown to modulate one's attention to emotional faces [88–90] and corresponding electrophysiological activities [91,92]. Mindfulness training could improve empathy as well [93]. Therefore, it is worthy examining whether empathy shows moderation effect on the effect of mindfulness training. Finally, visual search paradigm mainly reveals the parallel and serial processing in visual attention. More attentional tasks may be required to examine the training effect on the attentional processing of emotional stimuli. For examples, the dot-probe paradigm is an effective way to reveal attentional bias to visual stimuli [94,95]; and the dual-task paradigm can reveal the allocative attention to visual stimuli [96–98].

Declarations

Ethics approval. All procedures performed in this study involving human participants were in accordance with the ethical standards of the Ethical Committee of Human Research at Zunyi Medical University and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Ethical consent and informed consent was obtained from all participants before participation.

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Competing interests statement

The authors declare that they have no competing interests.

Author contributions

Bi Taiyong: conception, design, interpretation of data, funding acquisition, writing-original draft, writing-review & editing. **Kou Hui**: conception, design, data analysis, data interpretation, funding acquisition, writing-review & editing. **Li Xue**: design, acquisition of data. **He Yuxia**: acquisition of data. **Chen Siqi**: acquisition of data. **Xie Qinhong**: writing-review & editing.

Data availability

Anonymized data can be shared upon reasonable request by the corresponding author.

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Tables

Due to technical limitations, table 1 is only available as a download in the Supplemental Files section.

Figures

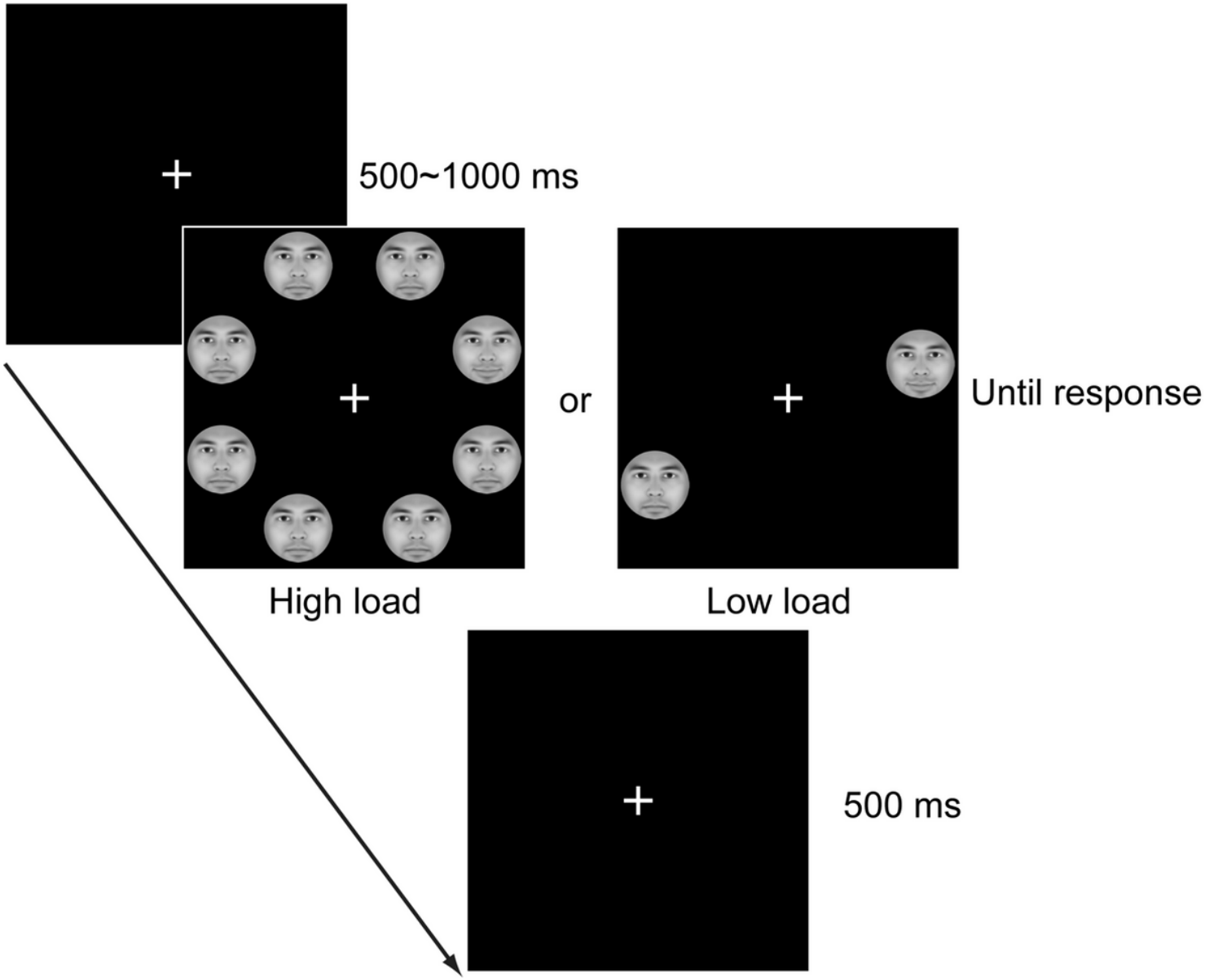

Figure 1

An example of the experimental procedure in the visual search task. The faces presented in the figure were created by FaceGen Modeller 3.1.

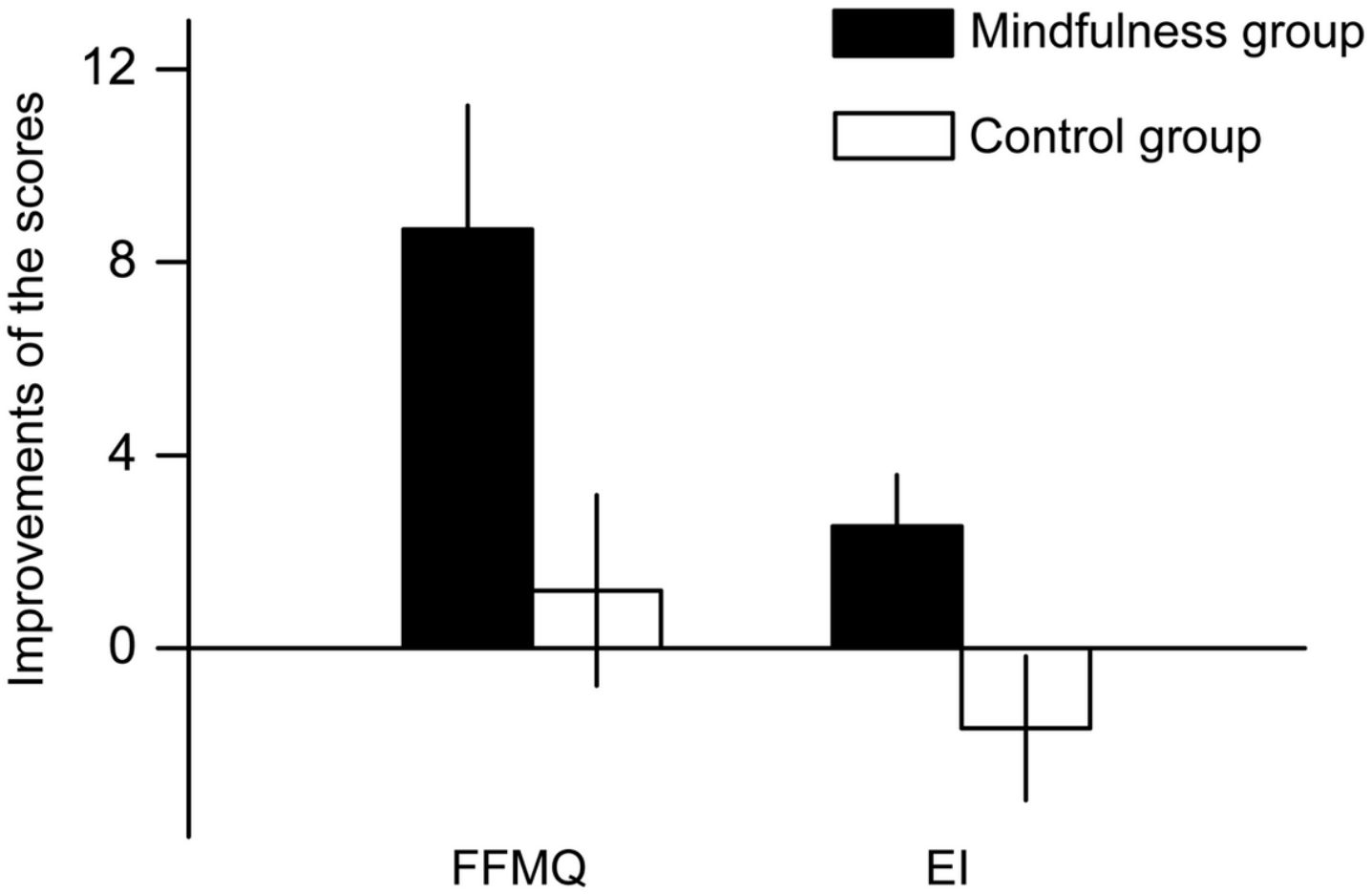

Figure 2

The improvements of the scores of FFMQ and EI. Improvements were calculated by subtracting the baseline (pre-training) scores from the post-training scores. Error bars denote one standard error of mean. FFMQ: Five Facet Mindfulness Questionnaire. EI: Emotional Intelligence.

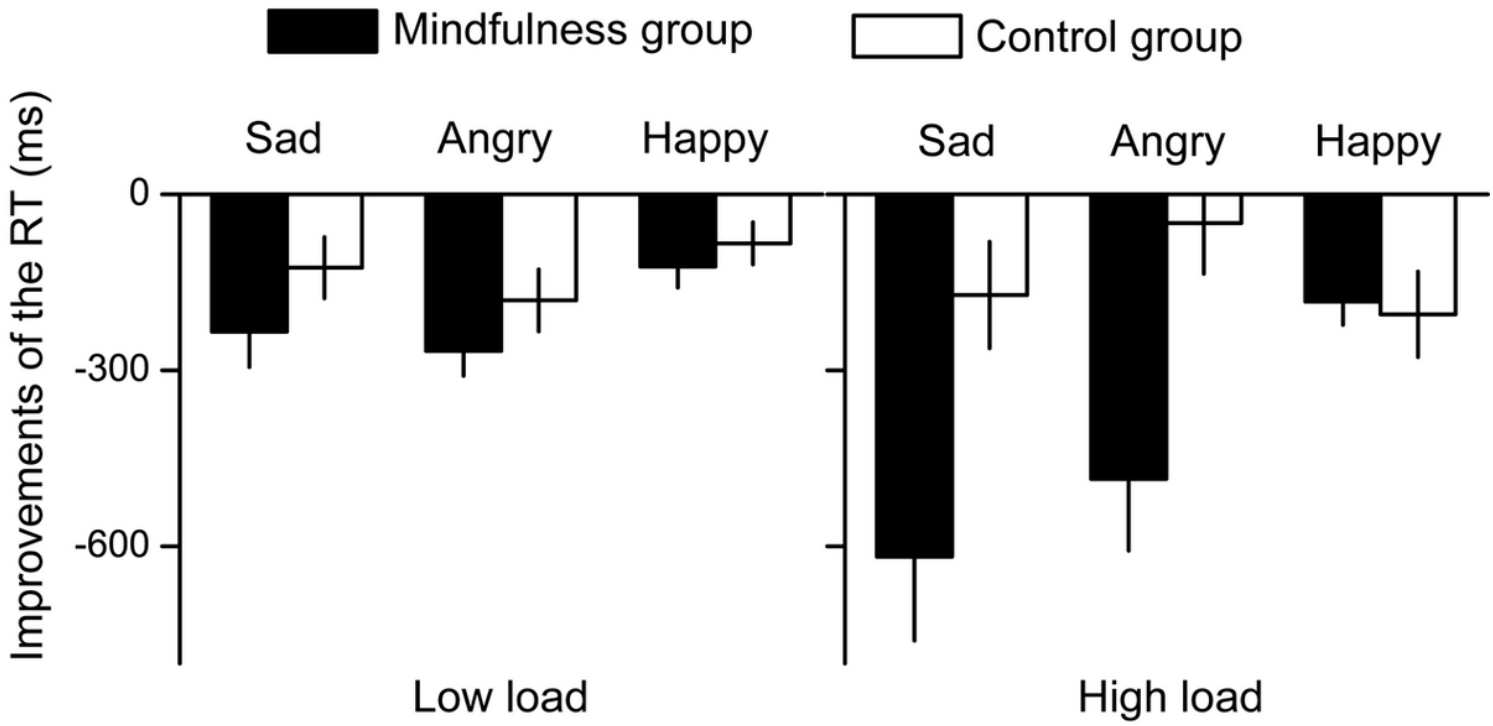

Figure 3

The improvements of the RT in the visual search task. Improvements were calculated by subtracting the baseline (pre-training) RTs from the post-training RTs. Error bars denote one standard error of mean. RT: Reaction Time.

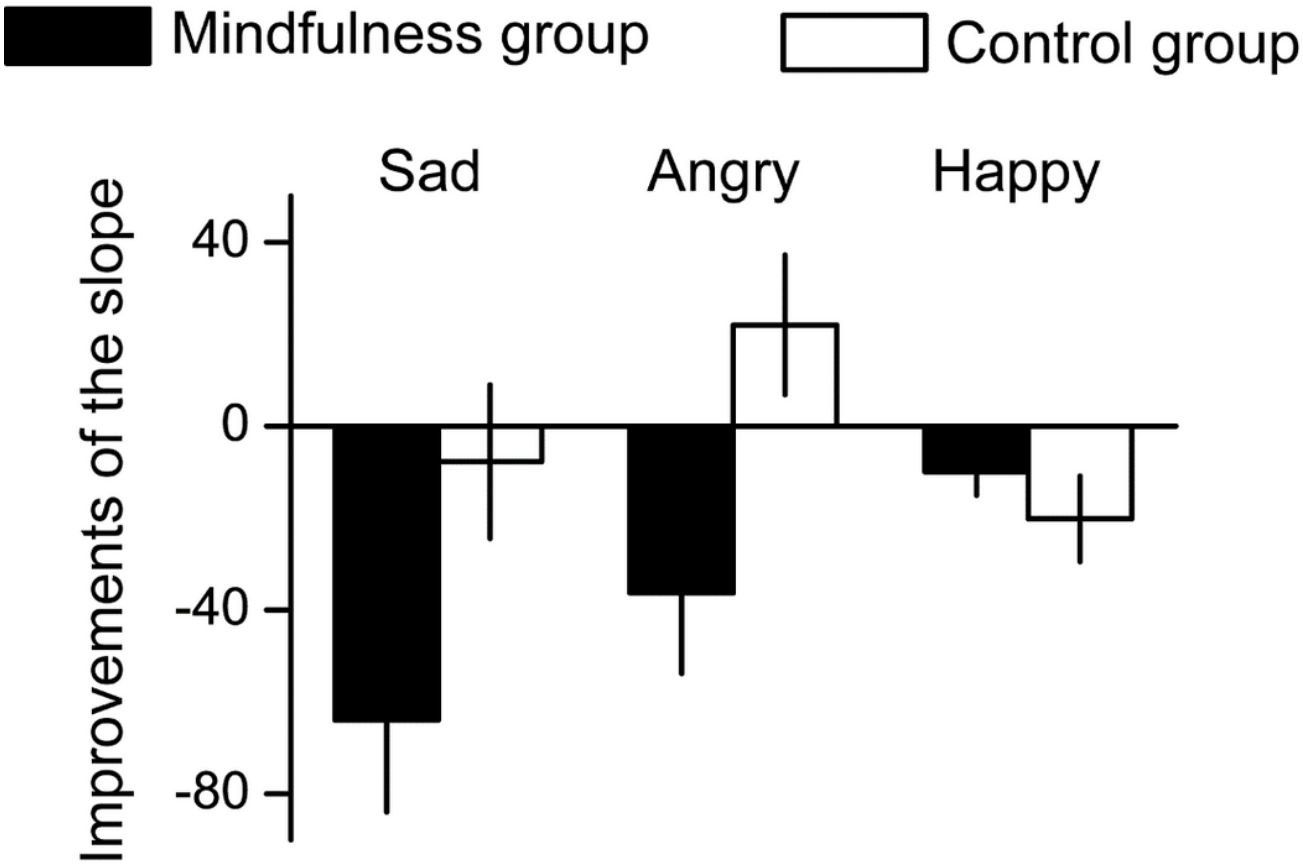

Figure 4

The improvements of the search slope in the visual search task. Search slope reflects the search efficiency of the target, i.e., a smaller slope indicates a higher efficiency. Improvements were calculated by subtracting the baseline (pre-training) slopes from the post-training slopes. Error bars denote one standard error of mean.

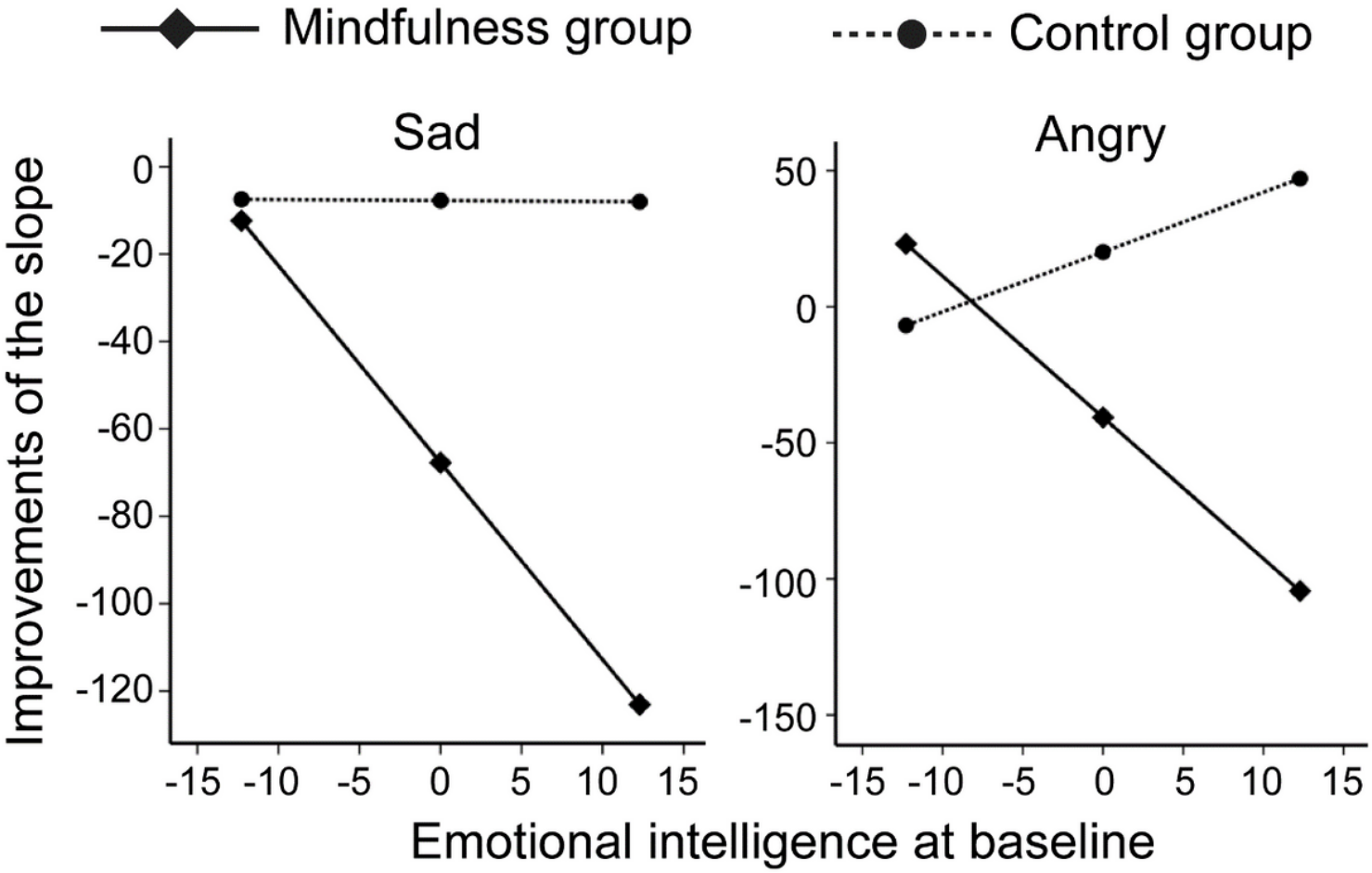

Figure 5

Emotional intelligence moderated the effect of mindfulness training on the search efficiencies of sad and angry faces. In the mindfulness group, individuals with higher emotional intelligence showed larger training induced improvements.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplemetary.docx
- Table1.pdf