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Abstract

Previous research suggests that mindfulness buffers stress reactivity and improves some health outcomes in stress-related diseases. However, little is known about the mechanisms facilitating this effect, such as the purported roles of monitoring and acceptance in mindfulness training. This study manipulates the components of monitoring and acceptance in a brief mindfulness meditation training randomized controlled trial, and evaluates whether they have dissociable effects on fostering attentional control, emotion regulation, and reducing stress reactivity. Participants (N=102) completed three days of training (the monitoring only condition, the monitoring and acceptance condition, the relaxation condition, and the reading control condition), followed by a Sustained Attention Response Task (SART) and an emotional Stroop task, which measured sustained attention and emotion regulation. Participants then completed their fourth training session followed by the Trier Social Stress Test (TSST), during which their systolic blood pressure was measured at two-minute intervals. Although no significant differences in blood pressure reactivity were observed, marginally significant differences were observed in sustained attention target discrimination rate, specifically with the highest rate in the relaxation training condition, followed by the monitoring and acceptance condition and the monitoring only condition. Results of reaction time of correct response to threatening stimuli revealed a trend of the fastest reaction times in the monitoring only condition, followed by the control conditions, with the slowest reaction times in the monitoring and acceptance condition. These findings suggest that both relaxation training and mindfulness training improve attentional control and alter emotion regulation, however, they fail to support any relative advantage of mindfulness training over relaxation training. We discuss the implications of these findings for the role of attention in mindfulness training and health.

Keywords: mindfulness, sustained attention, attentional bias, stress reactivity

Brief Mindfulness Meditation Training and Stress Reactivity: Mechanisms and Outcomes

Studies spanning the last fifteen years have found significant effects of mindfulness training on buffering biological stress reactivity (Brown et al., 2012), as well as on health outcomes in a broad range of stress-related disorders and diseases including depression relapse (Teasdale et al., 2000), inflammation (Malarkey et al., 2013), and HIV pathogenesis (Creswell et al., 2009), compared to control trainings. Mindfulness is the practice of monitoring and acceptance of present moment experience (Bishop, 2002). This study implements a brief 4-day mindfulness meditation intervention to test the effects of mindfulness training on attentional control, emotion regulation, and biological stress reactivity to the Trier Social Stress Test (TSST). This study dismantles the monitoring and acceptance components of mindfulness and it is predicted that both mindfulness training focusing on monitoring only and mindfulness training incorporating both monitoring and acceptance will improve attentional control, but it is predicted that the acceptance component is essential for improvements in emotion regulation and stress reactivity.

Monitoring and acceptance might produce different effects; specifically, monitoring alone is predicted to improve attentional control without engaging emotion regulation strategies that are needed during distressing or uncomfortable moment-to-moment experiences (i.e. during the TSST). Acceptance is action towards embracing present experience without judgment or attempts to change such experience (Hayes et al., 2006) and is proposed to be an essential facilitator of the observed stress-buffering effects of mindfulness training (Brown et al., 2012). Being trained to closely attend to and monitor moment-to-moment experiences may actually increase stress reactivity if the experience is uncomfortable or distressing and one does not accept their emotional response. The acceptance component might buffer automatic responses to stressful or threatening situations (Sauer et al., 2011). Previous findings suggest numerous benefits of acceptance training, including negative correlations between measures of acceptance and measures of job induced tension (Bond and Bunce, 2000), negative affectivity (Bond and Bunce, 2003), and traumatic stress symptom severity (Plumb et al., 2004; Hayes et al., 2006). It is predicted that acceptance is a necessary feature of mindfulness training interventions for improvements in emotion regulation and stress reactivity. It is predicted that four days of mindfulness meditation training emphasizing monitoring and acceptance will cause the greatest reduction in biological stress reactivity to the TSST, compared to a monitoring only mindfulness training condition, a relaxation training control condition, and a reading control condition.

Mindfulness training aims to alter ones attention to present-moment experience and this altering of one's ability to monitor moment-to-moment experience may cause improvements in attentional control (Chiesa and Malinowski, 2011; Malinowski, 2012). Mindfulness training changes attention processes, including the ability to sustain attention (e.g. Anderson et al., 2007; Chiesa et al., 2011; Moore et al., 2012; Zeidan et al., 2010), and may act as a top-down attention mechanism and change the early processing of stimuli (Allen et al., 2012; Brown et al., 2013; Modinos et al., 2010). To further investigate attentional control, this study employs the Sustained Attention Response Task (SART) as a measure of attention regulation and mind-wandering. Decreased attentional control and increased impulsivity are symptoms of ADHD and mindfulness training interventions have improved these deficiencies in patients with ADHD after 8 weeks of training (van de Weijer-Bergsma et al., 2011). It is therefore predicted that participants in the mindfulness training conditions (both the monitor only and monitor and accept training conditions) will exhibit greater sustained attention as measured by fewer omission errors and higher rates of sustained attention target discrimination during the SART.

Findings from previous studies suggest that mindfulness training enhances emotion regulation through the alteration of attention deployment and the minimization of rumination (Chambers et al., 2008; Jha et al., 2007; Kabat-Zinn, 1994). Emotion regulation is the process of influencing the initiation, experience, and expression of emotion (Gross, 1998), and may be a potential active mechanism of the stress-buffering effects of mindfulness. Previous studies have found that emotion regulation decreases elaboration on negative emotion and buffers the emotional impact of uncomfortable and distressing experiences, such as the TSST (Brown et al., 2012; Kabat-Zinn, 1994; Ludwig and Kabat-Zinn, 2008). It is predicted that participants in the monitoring only training condition will exhibit faster reaction times to threatening stimuli during an emotional Stroop task compared to control conditions because mindfulness decreases the time spent elaborating on the threat; however, monitoring and acceptance training will slow down reaction time by increasing overruling of automatic responses to threatening stimuli.

Methods

Participants

Participants (*N*=102) were recruited from the Carnegie Mellon University campus community and completed a 4-day study in the Health and Human Performance lab at Carnegie Mellon University. Inclusion criteria included being between the ages of 18 and 30 years old, in good mental and physical health, and taking no form of oral contraceptive. The average age of participants was 21 years old (*SD*=3.38). The ethnic breakdown was 31% Caucasian, 20% Asian American, 8% African American, 5% Latino/Hispanic, 6% Mixed, and 32% Other. All study procedure was approved by the Institutional Review Board at Carnegie Mellon University. All study data was collected between August 2013 and March 2014.

Procedure

Overview. Participants were recruited for a study investigating attention training and performance ability. Participants completed four 15-20 minute sessions of attention training over four consecutive days. All study procedure was conducted in a laboratory room. Participants were randomly assigned to one of four training conditions: mindfulness monitor and accept (*N*=29), mindfulness monitor only (*N*=26), relaxation control (*N*=30), or reading control (*N*=17) (see Training Conditions). On days one and four, participants were asked to report their treatment expectancies for the brief training they received (see Questionnaire Measures). After the third training session, the Sustained Attention Response Task and an emotional Stroop task (see Behavioral Measures) were administered. On the fourth day, blood pressure was measured in participants during a baseline period, training period, preparation period during which they prepared their upcoming speech, performance period (TSST), and recovery period (see Physiological Measures).

Day 1, 2 & 3 Procedure. At the beginning of the study participants were screened for inclusion criteria and provided informed consent. Baseline measures were taken for 5 minutes while the participant was seated. Participants were then instructed to complete their first session of attention training (delivered using prerecorded audio files via computer and headphones) (see Attention Training). To ensure experimenter blinding to training condition, audio files were stored in a folder labeled with the participant ID and each file was labeled with the correct day. During Day 1 participants completed brief study tasks, questionnaires, and an attention training while fitted with a blood pressure cuff, sensors to monitor autonomic nervous system activity, and a respiration belt to monitor respiration rate and volume throughout the entire session. Participants were monitored by experimenters in another room and were reminded to actively engage in the training if they appeared to be sleeping or distracted. Participants completed their second attention training session, brief study tasks, and questionnaires on the next consecutive day. Participants completed their third session of training, the SART, an emotional Stroop task, and questionnaires. Participants were compensated after each training session.

Day 4. During the fourth session participants completed study tasks, questionnaires and attention training while fitted with a blood pressure cuff, sensors to monitor autonomic nervous system activity, and a respiration belt to monitor respiration rate and volume throughout the entire session. Physiological measures were taken continuously throughout the session. Baseline measures were taken for 5 minutes while the participant was seated. Participants then listened to an audio recording of instructions for the performance task and were given three minutes to prepare. They then completed their training and, depending on the condition, were trained to maintain a mindful attentional stance or a relaxed attentional stance, or they listened to a neutral article on geography, culture, and the environment. The evaluators entered and the participant completed the two-part Trier Social Stress Test (Kirschbaum et al., 1993). Participants delivered a 5-minute speech detailing why they should be hired for a specific job position to a panel of non-accepting evaluators. After completion of the speech task, participants completed a measure of psychological stress perceptions (not reported) and continued with the simple calculation task for five minutes. Specifically, participants were instructed to count backwards from 2083 in 17-step sequences while the evaluators periodically interrupted the participant with non-evaluative feedback. The evaluators left the room and the participant recovered while seated for five minutes. Participants completed questionnaires and were debriefed and compensated for their time.

Materials

Training Conditions. Mindfulness has been defined as having two components, monitoring and acceptance (Bishop et al., 2004). Participants were randomly assigned in a 2:2:2:1 randomization procedure to complete four consecutive sessions of 15-20 minute attention trainings in one of four conditions. All conditions were matched for word count.

The monitor and accept condition consisted of mindfulness meditation training that fosters an objective and detached view of present-moment experiences by encouraging participants to be mindful of their breath and maintain an accepting and non-judgmental attitude (e.g. “Most importantly, there is no need in this practice to judge yourself negatively, because becoming distracted is just part of the practice of training your attention”) towards those experiences. (*N*=29).

The monitor only condition consisted of mindfulness meditation training that includes mindful breathing and mental labeling exercises to foster a mindful, objective, and detached (e.g. “There is no need to get caught up in any one particular sensation”) view of present-moment experiences (*N*=26).

The relaxation condition consisted of guided imagery exercises matched for attention, treatment expectancy, and relaxation effects that may account for any observed effects of mindfulness on stress. Guided imagery exercises included walking along a beach, through a forest, and through an imagined space (e.g. “You are entering into your imagination as if entering into a pleasant, inviting world”) (*N*=30).

The reading control condition contained excerpts from neutral articles on geography, culture, and the environment (e.g. “The trigger for this ecological shift—found nowhere else—is the onset of the *khareef,* the southwesterly monsoon”). Excerpts were matched for attention and treatment expectancy while providing a relative baseline comparison group (*N*=17).

Questionnaire Measures

Training Expectancy. Immediately after training on days one and four, participants were asked to indicate how much they believe, in that moment, the training they received was beneficial to them. Four items measured their belief in the relevance and effectiveness of the training on a scale of 1 (not at all) to 9 (very much). The items were “at this point, how logical does the attention training offered to you seem”, “how confident would you be in recommending this attention training program to a friend who wants to improve their attentional focus”, “at this point how much do you feel that attention training will help your cognitive performance at the end of the study”, and “how much do you feel that the techniques you learn in this program will be worth your time and effort”. A higher score indicates greater belief in the efficacy and relevance of their training as preparation for performance. The four questions were computed to produce composite training expectancy scores for day one and day four. The measure was adapted from the Credibility/Expectancy Questionnaire (Devilly and Borkovec, 2000) (study alpha = .95).

Behavioral Measures

Day Three Post-Training SART. The Sustained Attention to Response Task (SART) measures mind-wandering; mindfulness training was predicted to decrease mind-wandering and increase sustained attention as measured by omission errors and sustained attention target discrimination rates during the SART (Mrazek et al., 2012). Participants are instructed to press the spacebar in response to frequent nontargets and to refrain from pressing the spacebar in response to infrequent targets. Participants were presented with 34 NOGO trials and 281 GO trials, with a total of 315 trials. Participants viewed the stimuli for 250 ms with an interstimulus interval of 900 ms. Sustained attention discrimination rate (hit rate minus false alarm rate) and omissions errors (failing to press the spacebar during nontarget presentation) were used as indicators of sustained attention.

Day Three Post-Training Emotional Stroop. The emotional Stroop task measures emotion regulation; mindfulness training was predicted to decrease elaborative processing on threatening stimuli as measured by reaction time and accuracy (Anderson et al., 2007). Participants were presented with 40 threat words and 40 neutral words in counterbalanced order and instructed to identify the color of the ink that the word was presented in quickly and accurately. Ten threat stimuli (scorn, hostile, tense, naïve, immature, humiliated, pathetic, useless, inept, and stupid) and 10 neutral stimuli (scarf, theatre, slate, juice, wardrobe, definition, inactive, terrace, cards, refund) were presented in green, blue, red and yellow (Myers and McKenna 1996). Words between conditions were matched for length and word frequency (Francis and Kucera 1982). Stimuli with responses under 100 ms were excluded from analyses. Reaction time and accuracy were measured for the threat condition, with reaction time and accuracy for the neutral condition included as covariates.

Physiological Measures

Blood Pressure. Systolic (SBP) blood pressure was recorded every 2 minutes during the baseline epoch and attention training epoch on day one, as well as during the baseline epoch, speech preparation epoch, attention training epoch, performance epoch, and recovery epoch on day four. Participants remained seated during collection of cardiovascular measures.

Results

Preliminary Analyses

The TSST reliably evoked a biological stress response. Specifically, a paired samples t-test comparing day four baseline systolic blood pressure and performance systolic blood pressure confirmed that there was an increase from the baseline period (M=107.168 , SD=9.744) to the stress task period (M=135.841, SD=14.251) in systolic blood pressure, $t(97)= -24.643$, $p<.001$. Chi-square analyses confirmed that randomization of gender and ethnicity was successful; there were no significant study condition differences in gender, $\chi^2(3, N=107)=1.321$, $p=.724$ or ethnicity, $\chi^2(15, N=107)=6.179$, p=.977). A one-way ANOVA of trait mindfulness revealed no significant study condition difference in trait mindfulness, $F(3,98)= 1.707$, $p=.171$, $\eta^2=.050$. However, a one-way ANOVA unexpectedly indicated a difference in age across groups, $F(3,98)= 3.719$, $p=.014$, $\eta^2=.102$ [monitor only condition: (M=22.039, SD=3.605), monitor and accept condition: (M=20.241, SD=1.640), relaxation condition: (M=22.933, SD=3.832), reading control condition: (M=21.000, SD=3.623)]. Therefore, age was included as a covariate in all analyses. Training expectancies were also assessed in participants after training on Day 1 and Day 4 and it was predicted that there would be no condition differences in training expectancies. Consistent with this prediction, a one-way ANCOVA analyzing day four training expectancies by study condition found no significant difference between study conditions, $F(3,102)= 1.809$, $p=.150$, $\eta^2= .051$. A repeated measures ANCOVA revealed no significant time by study condition interaction, such that Day 1 to Day 4 treatment expectancies did not change differentially between study conditions $F(3,102)= 1.115$, $p=.347$, $\eta^2=.032$.

Main Analyses

SART. It was predicted that mindfulness training would increase sustained attention as assessed by the SART. Specifically, it was predicted that participant's sustained attention target discrimination would be greatest in the monitor only and monitor and accept conditions, followed by the relaxation and reading control conditions. A one-way ANCOVA of sustained attention target discrimination by study condition revealed that there was a marginally significant difference between study conditions in sustained attention target discrimination, $F(3,92)$: 2.304, $p=.083$, $\eta^2=.074$. Specifically, the relaxation control condition had the highest sustained attention target discrimination rate (M=261.000, SD=20.327), followed by the monitor and accept condition (M=259.111, SD=17.304), the monitoring only condition (M=254.4348, SD=16.91375), and the reading control condition (M=244.750, SD=35.042). The relaxation control condition appears to successfully facilitate sustained attention during the SART. It was also predicted that mindfulness training would prevent errors of omission, a common measure of lapses of attention during the SART task (Mrazek et al., 2012). We predicted that the mindfulness training conditions would have fewer attentional lapses during the SART, which was partially confirmed. Specifically, a one-way ANCOVA revealed a significant difference between study conditions on errors of omission during the SART, $F(3,92)= 2.898$, $p=.040$, $\eta^2=.091$. The reading control condition had a higher number of omission errors (M=12.813, SD=19.587), compared to the active training conditions. Although the monitor and accept training condition had the fewest attentional lapses (M=5.111, SD=5.794), there was little relative advantage of this condition and the monitor only training condition (M=6.261, SD=5.137) compared to the relaxation training control condition (M=5.269, SD=6.123).

Emotional Stroop. Based on previous findings that acceptance facilitates an overruling of automatic responses to threatening stimuli and slows down response time, it was predicted that the monitoring and acceptance condition would have the slowest reaction times to threatening stimuli (Sauer et al. 2011). It was predicted that the monitor only condition would lead to faster reaction times to threatening stimuli than monitor and accept training, relaxation training, or control training. A one way ANCOVA of reaction time for correct responses to threat stimuli by study condition, with reaction time for correct responses to neutral stimuli as a covariate, revealed a trend for differences in reaction time between study conditions, $F(3, 91)= 1.949$, $p=.128$, $\eta^2=.064$. The monitor and accept training condition had the slowest reaction time ($M=744.142$, $SD= 106.885$), followed by the relaxation training ($M=738.881$, $SD=77.227$), the control training ($M=723.873$, $SD=100.524$), and the fastest reaction time in the monitor only training condition ($M=716.264$, $SD=94.184$). In fact, there was a significant pair-wise difference in reaction times between the monitor and accept training relative to the monitoring training ($M_{diff}=35.712$, $p=.047$). We also predicted an increased number of correct responses to threatening stimuli in mindfulness conditions relative to the two control conditions. A one way ANCOVA of number of correct responses to threat stimuli by study condition, with number of correct responses to neutral stimuli as a covariate, revealed a significant difference in accuracy between study conditions, $F(3,91)=3.018$ $p=.034$ $\eta^2=.096$. The relaxation condition had the greatest number of correct responses ($M=39.500$, $SD=.659$), followed by the monitor and accept condition ($M=38.519$, $SD=1.553$), the reading control condition ($M=38.563$, $SD=1.263$), and the monitoring only condition ($M=38.292$, $SD=1.899$). There was a marginally significant difference between the relaxation condition and the monitor and accept condition ($M_{diff}=.788$, $p=.052$). There was a significant pair-wise difference between the relaxation condition and the monitor only condition (M_{diff}=-1.088, *p*=.007), and between the relaxation condition and the reading control condition (M_{diff}=1.025, *p*=.025).

Systolic Blood Pressure. We predicted stress buffering effects in only the monitor and accept condition, relative to the other training conditions. This prediction was not supported, a repeated measures ANCOVA comparing the training conditions on systolic blood pressure reactivity over time was not significant: condition by time interaction $F(3,89)=1.103$, $p=.352$, $\eta^2=.036$. Moreover, a follow-up ANCOVA comparing peak TSST task stress reactivity between groups was also not significant, $F(3,93)= 1.162$, $p=.329$, $\eta^2=.036$. Although not significant, the peak systolic blood pressure response was highest in the monitor only condition (*M*=138.495, *SD*=17.936), followed by the reading control condition (*M*=137.216, *SD*=14.360), the monitor and accept condition (*M*=136.013, *SD*=13.504), and the relaxation condition (*M*=132.542, *SD*=10.843).

Discussion

Our goal was to dismantle the active components of mindfulness (monitoring and acceptance) and test for their differential effects on attentional control, emotion regulation, and stress reactivity. Based on previous findings that mindfulness training improves a range of attentional skills, including sustained attention, we hypothesized that mindfulness training would lead to greater sustained attention target discrimination and fewer omission errors during the SART (Chiesa et al., 2011; Moore et al., 2012; Mrazek et al., 2012; van de Weijer-Bergsma et al., 2012; Zeidan et al., 2010). Analyses revealed a marginally significant difference between study conditions in measures of sustained attention on the SART, however, the highest rate of sustained attention target discrimination was found in the relaxation training condition, followed by the monitoring and acceptance training, monitoring only training, and finally the reading control condition. These trends, along with findings from previous studies, support an important potential role for active relaxation training and attentional control. If relaxation training and mindfulness training have similar effects on attentional skills, relaxation may also cause improvements in health outcomes thought to be driven by improvements in attentional skills (Chiesa and Malinowski 2011, Malinowski 2012).

We found a significant difference between study conditions in a secondary measure of sustained attention, the number of omission errors, showing the greatest sustained attention after monitoring and acceptance training, followed by relaxation training, monitoring only training, and the reading control condition. However, these findings fail to support our prediction that the monitoring and acceptance and monitoring only training conditions equally improve attentional control and produce significantly different outcomes in attentional control relative to the relaxation training condition. Similar null findings were also found by Anderson and colleagues, and it was suggested that mindfulness may be more likely to produce changes in “the quality of awareness of present moment experience” rather than in basic attentional skills (Anderson et al., 2007). These findings facilitate increased specificity in the predicted effects of mindfulness training on attention.

Emotion regulation, as measured by the emotional Stroop, was proposed to be an important mechanism facilitating the stress-buffering effects of mindfulness, based on previous findings that mindfulness improves emotion regulation (Brown et al. 2013, Modinos et al., 2010). However, the results did not support this prediction and revealed a significant overall difference between study conditions in the number of correct responses to threatening stimuli with the greatest accuracy in the control conditions compared to the mindfulness conditions. No significant overall difference was found between study conditions in reaction time of correct responses to threat stimuli, but the monitoring and acceptance mindfulness condition had the slowest reaction time, followed by the relaxation training, reading control condition, and the fastest reaction times in the monitoring only condition. These trends support an alternative account that the acceptance component results in an overriding of automatic responses and slows down reaction times. These findings are important because they begin to address unanswered questions in the literature regarding the effects of mindfulness on emotional functioning and emotion regulation (Brown et al. 2012; Brown et al., 2013; Chambers et al. 2008; Ludwig and Kabat-Zinn 2008; Modinos et al., 2010).

The results showed that the social evaluative stress task (TSST) elicited a biological stress response as expected (Kirschbaum et al., 1993), however, we did not find significant differences in systolic blood pressure response between study conditions as predicted. These null findings contradict previous research suggesting that 8-weeks of mindfulness training buffers biological markers of stress reactivity, including systolic blood pressure (Anderson et al., 2007; Bishop, 2002; Nyklicek et al., 2013). Aspects of the study that may have contributed to null findings include limited exposure to training, subtle differences between the two mindfulness training conditions, and small samples sizes in this large four-group study design. This finding adds boundary conditions for stress-buffering effects of mindfulness training.

Thus, while the current study fails to differentiate the effects of mindfulness training from the effects of relaxation training, we do find that mindfulness training shifts the way one attends and reacts to moment-to-moment experience relative to a reading control condition. We conclude that finding effects of mindfulness on stress response requires sensitive biological measures. It is suggested that mindfulness improves emotion regulation through the acceptance component of mindfulness and the present findings raise a number of questions to be addressed in future research. What are the similarities and differences in the effects of relaxation training and mindfulness training on stress reactivity and health outcomes of stress-related diseases and disorders? Is emotion regulation an active mechanism facilitating the observed stress-buffering effects of brief mindfulness interventions? The potential benefits of training that aims to improve one’s stress response necessitates research that addresses these key questions.

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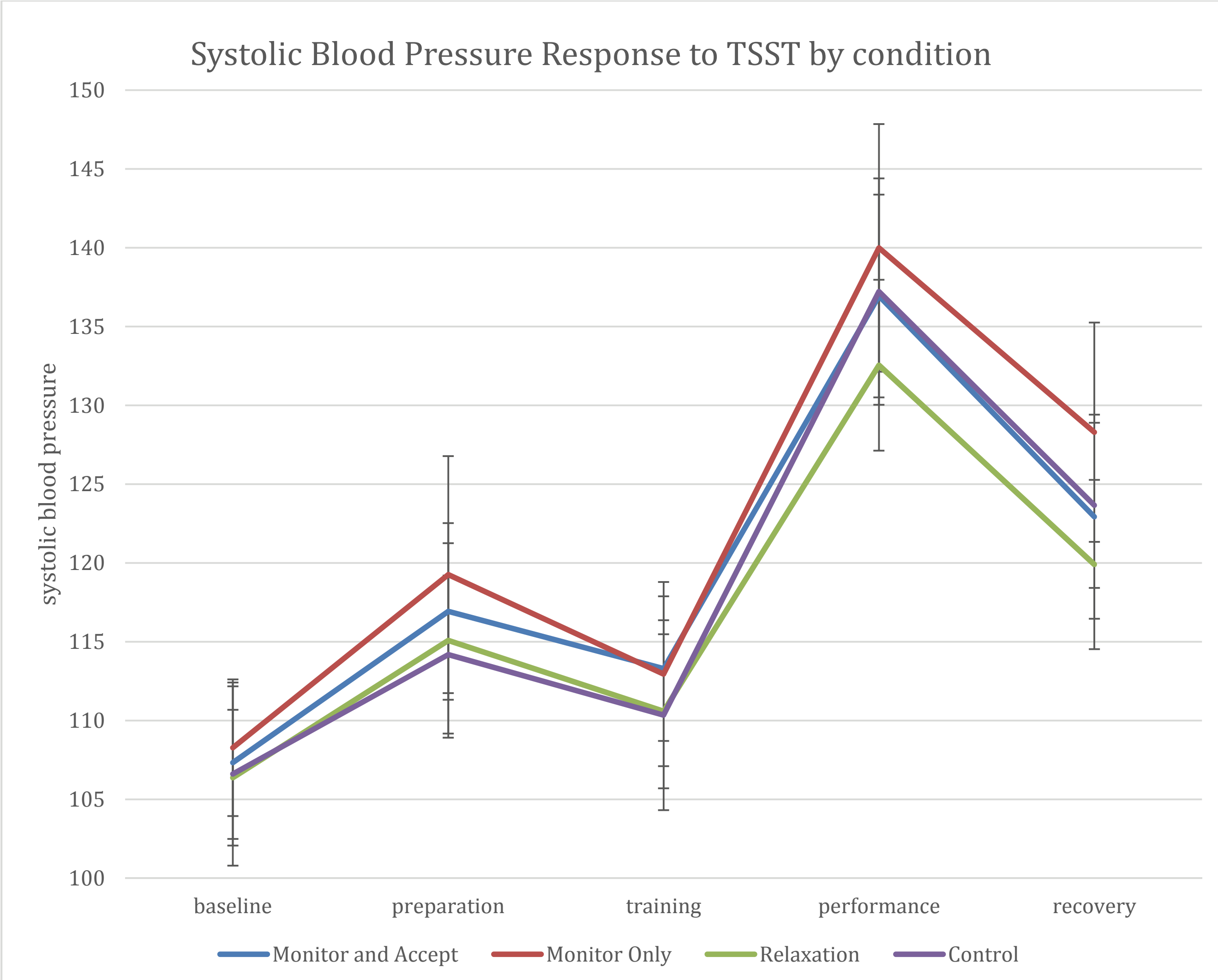

Figure 1. Systolic blood pressure over time by Condition.

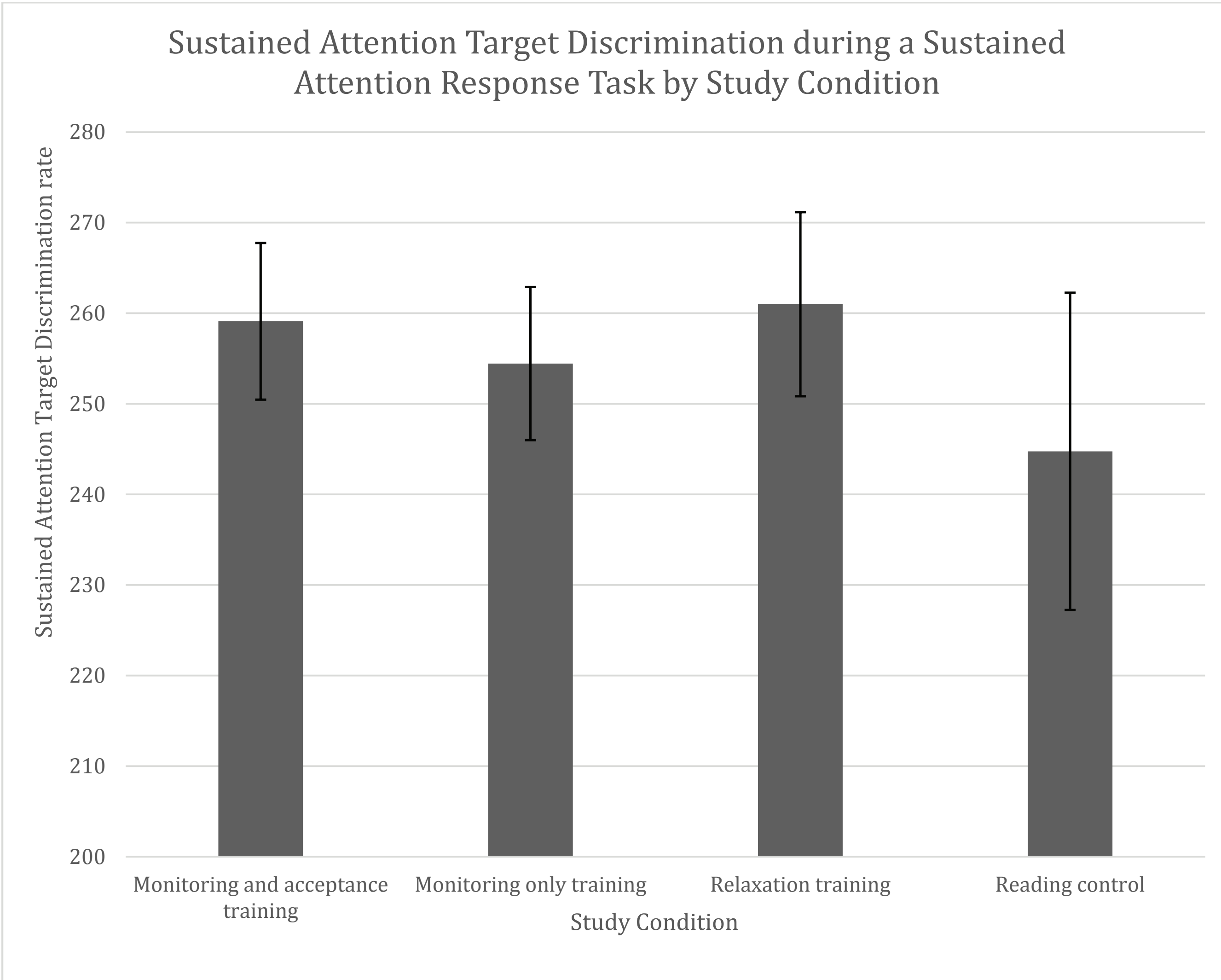

Figure 2. Sustained Attention Target Discrimination during the SART by Condition.

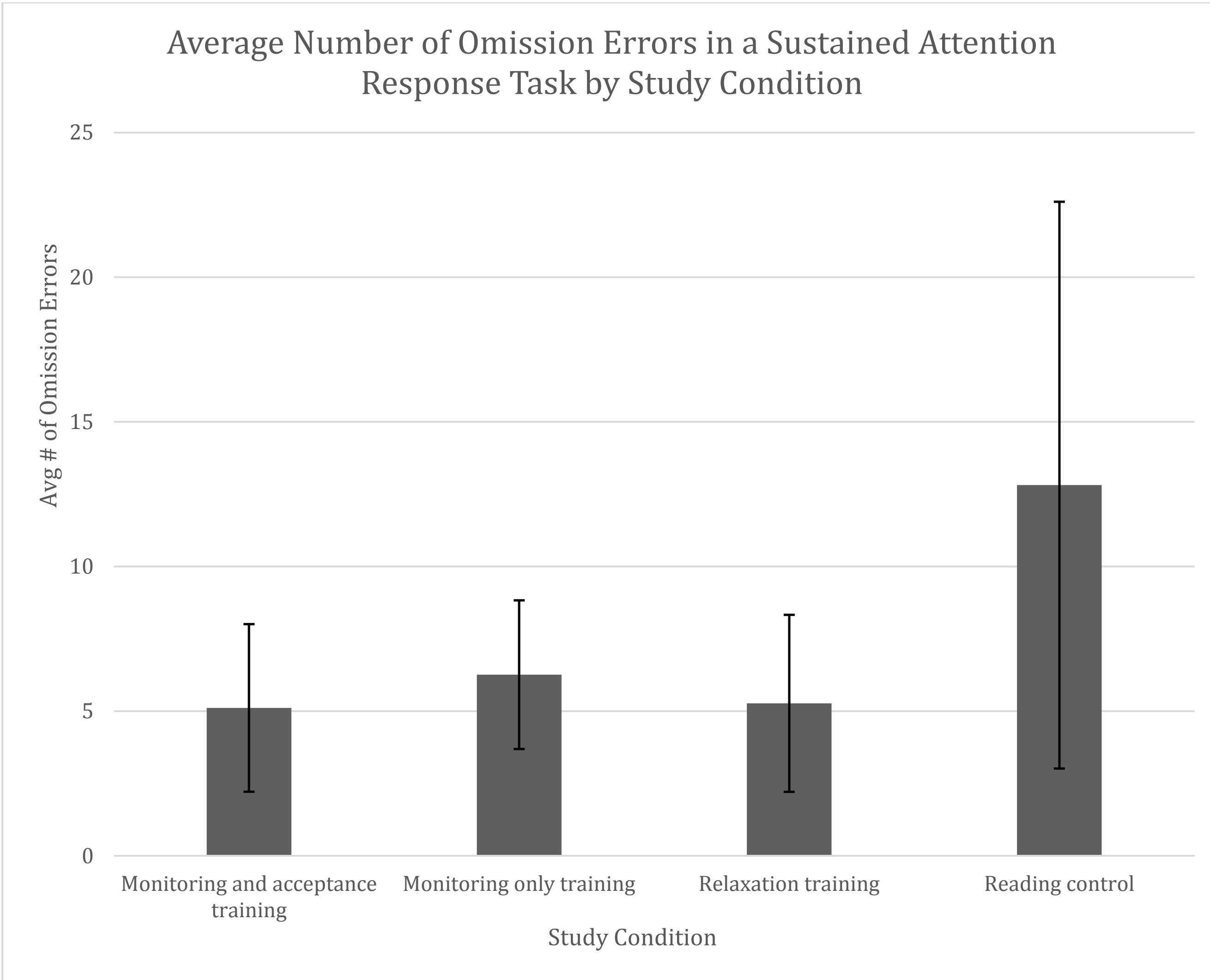

Figure 3. Omission Errors during the SART by Condition.

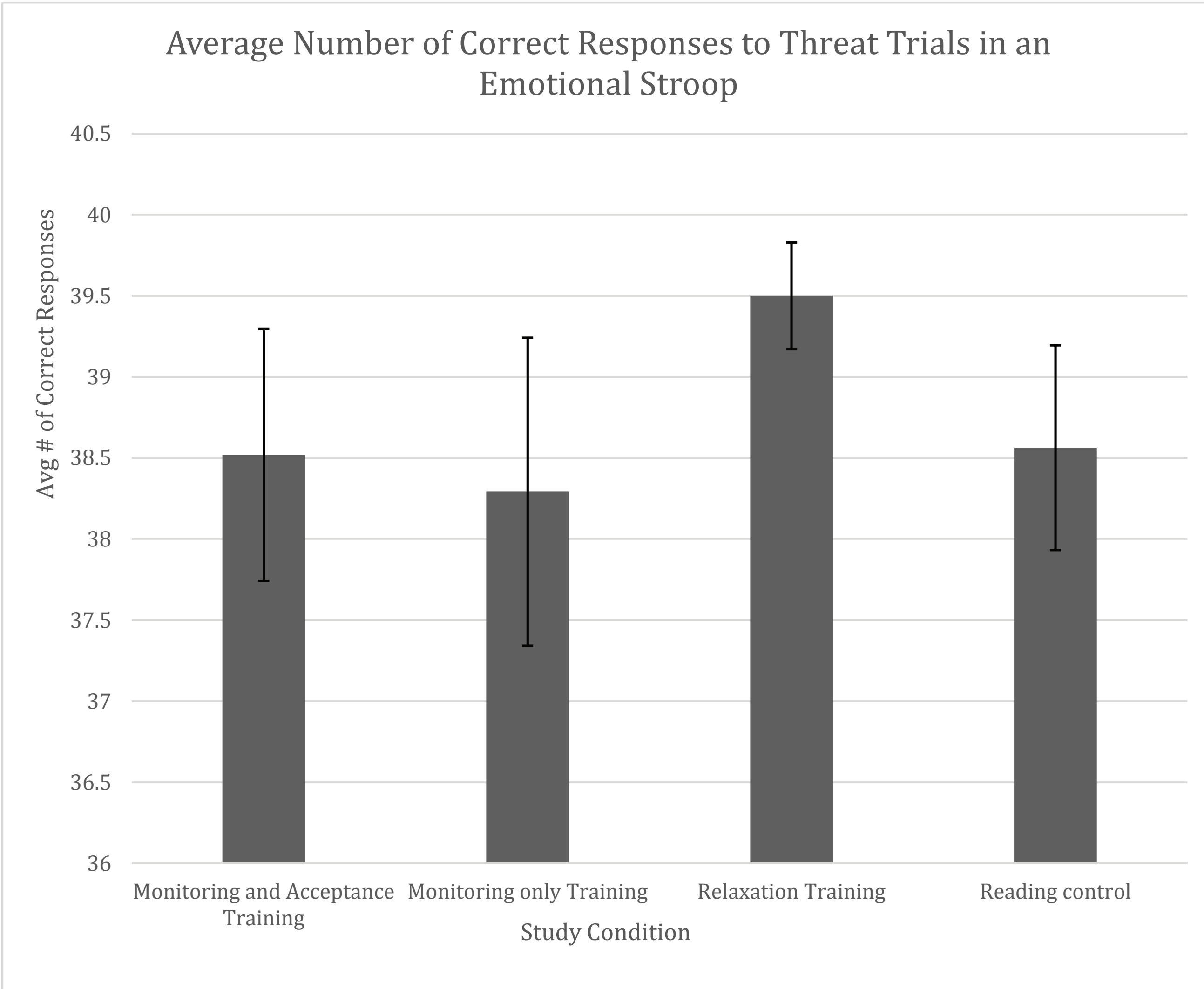

Figure 4. Correct Responses to Threat Stimuli in an Emotional Stroop by Condition.

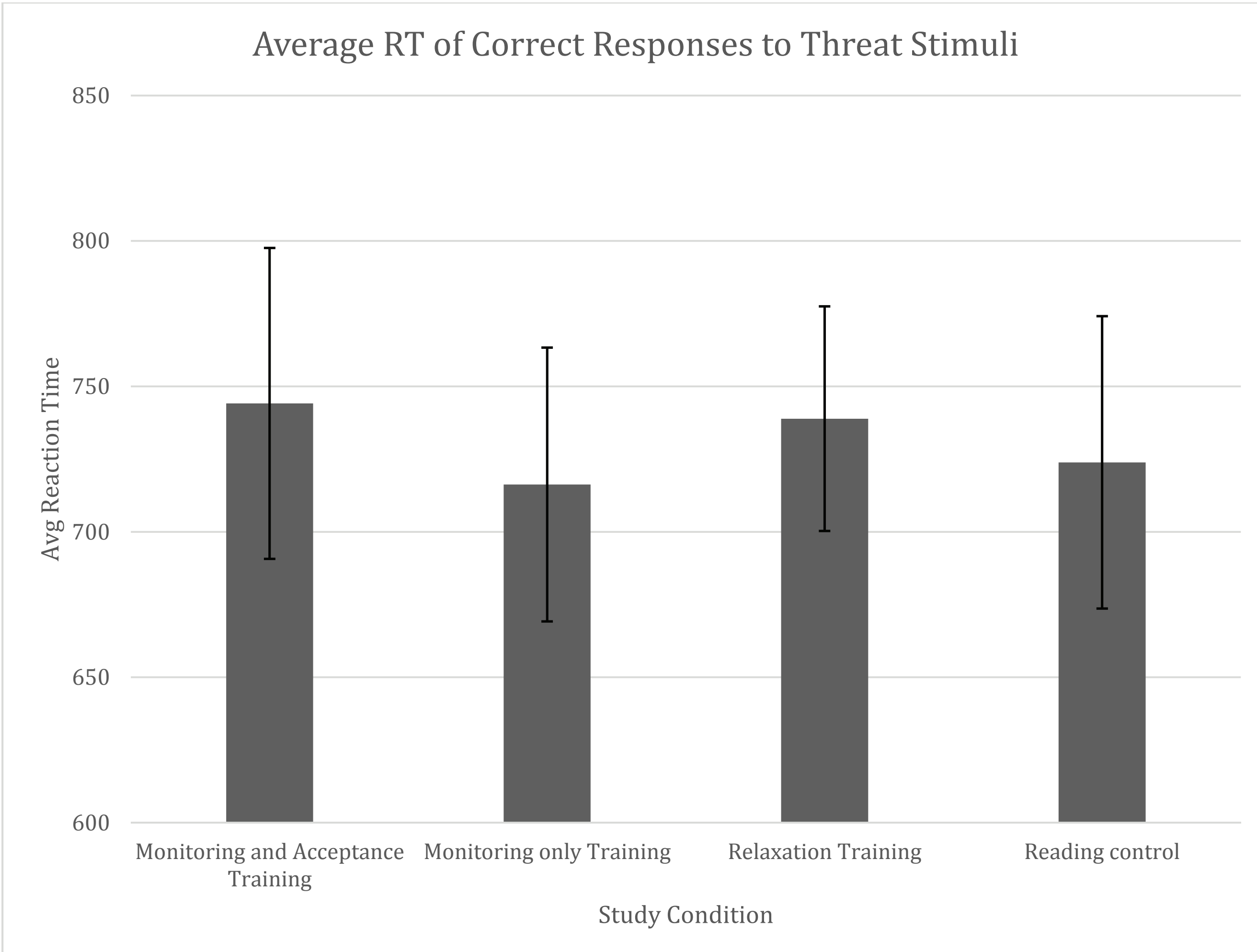

Figure 5. Average Reaction Time of Correct Responses to Threat Stimuli in an Emotional Stroop by Condition.