Appl Psychophysiol Biofeedback (2014) 39:213–217
DOI 10.1007/s10484-014-9258-5

Short Term Integrative Meditation Improves Resting Alpha Activity and Stroop Performance

Yaxin Fan · Yi-Yuan Tang · Rongxiang Tang · Michael I. Posner

Published online: 25 September 2014

Abstract Our previous research showed that short term meditation training reduces the time to resolve conflict in the flanker task. Studies also show that resting alpha increases with long term meditation practice. The aim of this study is to determine whether short term meditation training both increases resting alpha activity and reduces the time to resolve conflict in the Stroop task and whether these two effects are related. Forty-three Chinese undergraduates were randomly assigned an experiment group given 5 days meditation training using integrative body-mind training (IBMT) and a relaxation training control. After training, only the IBMT group showed decreased conflict reaction time (RT), and increased resting mean alpha power. Moreover, the higher the enhancement of resting alpha power, the stronger the improvement of conflict RT. The results indicate that short term meditation diffusely enhances alpha and improves the ability to deal with conflict and moreover these two effects are positively related.

Keywords Integrative body-mind training (IBMT) · Attention · Stroop · EEG · Resting alpha power

Introduction

Recent studies suggested that short term meditation affects the time to resolve conflict in the flanker task (Tang et al. 2007). Stroop conflict effect refers to the longer time that it takes to name the ink color of a color-word when the ink color and color-word are incongruent (e.g., 'RED' in blue ink) as compared to congruent (e.g., 'RED' in red) (Stroop 1935). Conflict in the Stroop task is influenced by long term meditation practice (Chan and Woollacott 2007), but it remains to be seen if it would be improved with only few hours of practice as found for the flanker task.

Resting alpha activity reflects and predicts cognitive performance (Klimesch 1999; van der Hiele et al. 2008). Evidence suggests that the stronger resting alpha frequency power, the better cognitive performance (Klimesch 1999; Ramos-Loyo et al. 2004; van der Hiele et al. 2008). Alpha (8–13 Hz) and/or theta (4–8 Hz) power increases are often observed when meditators are evaluated during meditation compared with control conditions (Aftanas and Golocheikine 2001; Takahashi et al. 2005; Tang et al. 2009), and alpha power is stronger at rest in long term meditators compared with nonmeditator controls (Aftanas and Golosheykin 2005; Travis 1991). However, no evidence indicated that short term meditation practice can increase resting alpha power. Since greater resting alpha is thought to improve cognitive performance we hypothesize that there should be a positive correlation between increase in alpha and reduction of time to resolve Stroop conflict.

Y. Fan
Dalian Blood Center, Zhongshan District, Dalian 116001, China

Y.-Y. Tang (✉)
Department of Psychological Sciences, Texas Tech University, Lubbock, TX 79409, USA
e-mail: yiyuan.tang@ttu.edu

R. Tang
Department of Psychology, The University of Texas at Austin, Austin, TX 78705, USA

M. I. Posner
Department of Psychology, University of Oregon, Eugene, OR 97403, USA

In the present study, we investigated the effects of short term IBMT on resting alpha activity and Stroop conflict performance. Forty-three Chinese undergraduates were randomly assigned to an 5 days IBMT group or to a relaxation training control. Before and after the training, resting EEG activity was recorded prior to performing Stroop test. We hypothesize that after 5 days meditation training, resting alpha activity will be increased and the ability to reduce conflict in the Stroop task will increase. Moreover, the two effects should be positively correlated.

Materials and Methods

Subjects

Subjects were recruited through a campus notice at Dalian University of Technology. Interested subjects then filled in a questionnaire, containing exclusion criteria designed to reduce confounding factors that have been shown to affect behavioral and electrophysiological dependent measures. Forty-three Chinese undergraduates without any training experiences, between 19 and 22 years of age (mean = 21.03), participated in this study. All subjects are right-handed, had no history of neurological or mental problems, and had normal or corrected-to-normal vision and normal color vision. The study was approved by a local Institutional Review Board, and informed consent was obtained from each participant.

Subjects were randomly assigned to an experimental group and a control group. Twenty-one experimental subjects (10 males and 11 females) continuously attended practice of IBMT for 5 days, whereas twenty-two control subjects (11 males and 11 females) received an equal period of relaxation training.

Training Methods

IBMT involves several body–mind techniques including body relaxation, mental imagery and mindfulness training, accompanied with soft background music and guided by a qualified coach (Tang et al. 2007, 2012). The method emphasizes no effort to control thoughts, and achievement of a state of restful alertness that allows a high degree of awareness of body, mind and environment (Tang et al. 2007, 2009, 2012; Tang and Posner 2009).

Relaxation training is a form of muscle relaxation technique very popular in the West. It involves the relaxing of different muscle groups over the face, head, shoulders, arms, legs, chest, back, and abdomen, guided by the coach and accompanied with soft background music. With eyes closed and in a sequential pattern, one is forced to concentrate on the sensation of relaxation, such as the feelings of warmth and heaviness. This training helps the participant achieve physical and mental relaxation and calmness (Bernstein and Borkovec 1973; Tang et al. 2007).

Experimental Procedure

Before training, qualified coach gathered the subjects to introduce the structure of the program and the training methods, answer questions, and also set up the exact time, training room, and discipline for the group practice. All subjects completed group-training sessions for 5 days.

Subjects separately followed the IBMT and relaxation instructions guided by the coaches in different rooms every night for 20–30 min, the total practice is around 2 h. Following each training session, every subject filled out a self-report questionnaire and evaluated the practice. The coaches gave brief and immediate responses to questions from the participants as required. The qualified coach had completed IBMT or relaxation training and demonstrating the ability to lead the group training.

Before and after 5 days of training, 5 min eyes-open resting EEG activity was recorded prior to Stroop task. Subjects were instructed not to smoke or use alcohol on the day of test, and have no physical activity for four hours prior to the test. All subjects successfully completed the program as required without missing sessions.

Electroencephalographic (EEG) Recordings and Data Processing

Brain electrical activity was recorded for 5 min with open eyes at rest from F3, Fz, F4, F7, F8, C3, Cz, C4, T7, T8, P3, Pz, P4, O1, Oz, O2 according to the 10–20 International System. The reference electrode was placed on the FCz, while ground was linked to the AFz. Signals were collected at 500 Hz samples and impedances kept below 5 kΩ. Electro-oculogram (EOG) data were recorded to detect eye movement artifacts.

Offline, the BrainVision analyzer Software (Version 1.05) was used. The EEG was digitally low-pass filtered at 40 Hz, and transformed to an average reference. Artifact-free 2 s epoch data were submitted to a fast Fourier transform. Power was computed for the alpha (8–13 Hz) frequency band (μV2).

Stroop Task

Congruent stimuli consisted of the three color words (红, 黄, 蓝) (red, yellow, blue) written in the same color as the stimulus (e.g., the word '红' (red) written in red color). The incongruent stimuli consisted of the same three words with the two display colors not matching the word meaning (e.g., the word '黄' (yellow) written in red ink). In the neutral condition, two no-color words (球, 表) (ball, watch)

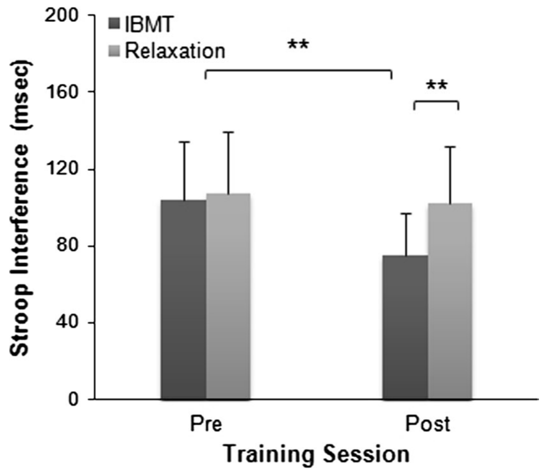

Fig. 1 Comparison of IBMT and Relaxation group in Stroop interference pre- and post-training. Stroop interference is the result of incongruent reaction time minus the congruent reaction time. **$P < 0.01$

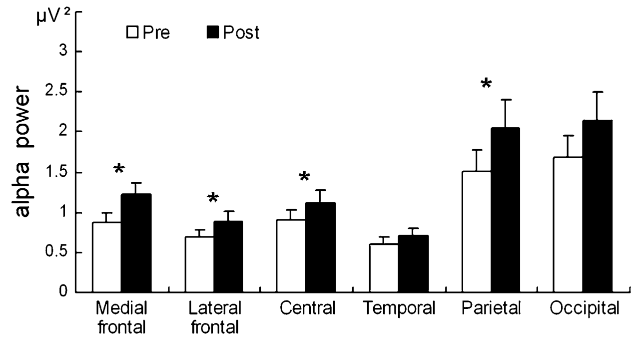

Fig. 2 Pre- and post-assessment resting alpha power in the IBMT group. *Error bar* indicates 1 SEM. *$P < 0.05$

were presented in each of the three colors. The size of the Chinese characters was Song Ti No. 28.

Subjects rest their right middle three fingers on the three keys of the response pad, each key represented one color. The practice phase was designed to rehearse the mapping of colors onto fingers. The formal test consisted of 144 trials (48 stimuli for each congruency condition). The trial order is as follows: the fixation point appeared 600 ms, one word appeared for 150 ms in a random order, then the empty screen appeared 1,750 ms. Subjects were asked to identify the color in which the stimulus was written by pressing the key corresponding to the ink color as fast and accurately as possible.

Statistical Analyses

All statistical analyses were performed using SPSS 13.0 for Windows. Data were examined by repeated measures ANOVAs. Pearson' test was used for correlation analysis.

Results

Behavioral Data

Prior to training, two groups did not differ in behavioral data ($P > 0.05$). Figure 1 showed the comparison of IBMT and Relaxation group in Stroop interference at pre- and post-training ($P < 0.01$). Stroop interference is the result of incongruent reaction time minus the congruent reaction time (RT).

Using RT and accuracy as dependent variables, we conducted a repeated measured ANOVAs with the between group factor of Group (IBMT and relaxation), the within-subjects factors of Session (Pre and Post) and Trial type (Congruent, Incongruent and Neutral). The RT analysis revealed significant main effects of the Session ($F(1,41) = 53.71, P < 0.001$) and Trial type ($F(2,82) = 74.28, P < 0.001$), as well as significant interaction for Session × Group ($F(1,41) = 18.86, P < 0.001$). A main effect for Trial type ($F(2,82) = 48.67, P < 0.001$) was the only significant result obtained for accuracy.

Post-hoc tests for trial type revealed significantly longer RT and more errors in the incongruent than congruent condition for both groups in the pre- and post-session. Conflict effects refer to the difference between congruent and incongruent conditions.

After training, IBMT group showed significantly lower RTs than control group in the congruent RT ($F(1,41) = 4.532, P < 0.05$), the incongruent RT ($F(1,41) = 9.450, P < 0.01$), the neutral RT ($F(1,41) = 6.911, P < 0.05$), as well as conflict RT ($F(1,41) = 9.190, P < 0.01$) .

For accuracy analysis, no significant differences were found between two groups at each session, nor between two sessions within each group ($P > 0.05$). This suggested that the superior performance in Stroop RT in the post-session was not due to participants responding less carefully.

EEG Data

Prior to training, the groups did not differ in EEG data ($P > 0.05$). Using resting mean alpha power as dependent variables, we conducted a repeated measured ANOVAs with the between group factor of Group (IBMT and relaxation), the within-subjects factors of Session (Pre and Post) and scalp locations [medial frontal (F3–Fz–F4), lateral frontal (F7–F8), Central (C3–Cz–C4), Temporal (T7–T8), parietal (P3–Pz–P4), and Occipital (O1–Oz–O2)]. The analysis revealed significant main effects of location ($F(5,205) = 7.651, P < 0.001$), and significant interactions for Session × Group ($F(1,41) = 6.126, P < 0.05$). The pre

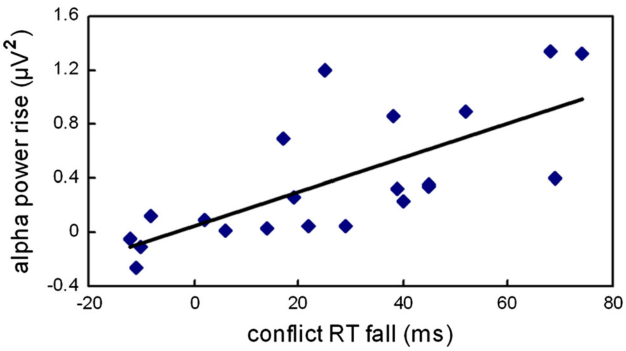

Fig. 3 Correlation between resting alpha power rise at medial frontal scalp location and conflict RT fall for the IBMT group

versus post difference in the resting alpha power was significant only for the IBMT group at medial frontal ($t(20) = -2.436$, $P = 0.021$), lateral frontal ($t(20) = -2.337$, $P = 0.031$), central ($t(20) = -2.415$, $P = 0.028$), and parietal ($t(20) = -2.120$, $P = 0.047$), scalp locations (Fig. 2).

Relationship Between Resting Alpha Power Rise and Conflict RT Fall

To examine whether the reduction in conflict RT in the IBMT group was related to the increase in resting alpha power, pre-post difference scores were computed for both measures. Pearson correlation analysis revealed that the reduction in conflict RT in the IBMT group is negatively correlated with the resting alpha power at medial frontal ($r = -0.714$, $P < 0.001$) (Fig. 3), lateral frontal ($r = -0.598$, $P < 0.01$), central ($r = -0.538$, $P < 0.05$), and parietal ($r = -0.624$, $P < 0.01$), scalp locations.

Discussion

The behavioral data were consistent with our previous work that short term integrative meditation improves executive attention (Tang et al. 2007). The EEG data were consistent with hypothesis that after 5 days IBMT training, resting alpha power will be increased. Moreover, the higher the enhancement of resting alpha power, the stronger the improvement of conflict RT.

The results showed that resting alpha power increases in the IBMT group are significant over medial and lateral frontal, central, parietal, but not temporal and occipital regions. This finding may reflect the importance of frontal (e.g. anterior cingulate cortex and insula) and of parietal areas in various functions of attention and self-regulation (Petersen and Posner 2012; Tang and Posner 2009).

Age-related decline in Stroop performance is linked with the magnitude of task-related EEG alpha activation over medial and lateral frontal and parietal regions (West and Bell 1997). Resting brain alpha activity could reflect a functional steady state which might represent the brain's latent cognitive processing capability (Ramos-Loyo et al. 2004). After IBMT training, the maximum significant effects of pre versus post difference in the resting alpha power and correlation coefficient were both in medial frontal area. The medial frontal cortex, particularly in the anterior cingulate cortex (ACC), has been shown to play a critical role in self-regulation of cognition and emotion (Posner et al. 2007; Tang et al. 2007, 2009). The present results thus suggest that short term meditation diffusely enhances the brain cognitive state particularly in the medial frontal areas including ACC, and improves the cognitive ability to deal with conflict. However, it is not possible to conclude from the correlation a causative link.

Our previous studies have shown that short term IBMT improves executive attention, enhances positive moods, increases neural activity in the ACC and connectivity of the ACC to other brain regions, and induces white matter changes in the ACC (Tang et al. 2007, 2009, 2010; Tang and Posner 2009; Tang et al. 2012). IBMT improves attention and self-regulation by changing the interaction between the central (brain) and the autonomic (body) systems (Tang et al. 2009). IBMT integrates several key components of body mind techniques which can help and accelerate practitioner access to body mind harmony and balance states (Tang and Posner 2009; Tang et al. 2012). Brain alpha activity increases are associated with physical relaxation and lower levels of anxiety and feeling of calmness and positive affect (Hardt and Kamiya 1978; Takahashi et al. 2005). Taken together, short term IBMT facilitates an effective body mind state, and thus improves resting alpha activity and the ability of the self-regulation.

A recent fMRI study comparing the performance of meditators and matched controls in the Stroop task reported that non-meditators showed greater activity than meditators in the right medial frontal, middle temporal, precentral and postcentral gyri and the lentiform nucleus during the incongruent conditions (Kozasa et al. 2012). It is not clear how these changes in brain activation relate to the changes in resting state alpha reported in this study. Future neuroimaging and EEG studies may provide more precise relationship between resting state and task performance as well as the order of neuroplasticity.

Conclusion

Short term integrative meditation increases resting alpha power, diffusely enhances the brain cognitive state particularly in the medial frontal area, and improves the cognitive ability to deal with conflict. In sum, IBMT is an easy and effective way for improvement in brain function and self-regulation.

Acknowledgments This study is supported by the Office of Naval Research.

Conflict of interest There are no conflicts of interest.

References

Aftanas, L. I., & Golocheikine, S. A. (2001). Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: High-resolution EEG investigation of meditation. *Neuroscience Letters, 310*(1), 57–60.

Aftanas, L., & Golosheykin, S. (2005). Impact of regular meditation practice on EEG activity at rest and during evoked negative emotions. *International Journal of Neuroscience, 115*(6), 893–909.

Bernstein, D. A., & Borkovec, T. D. (1973). *Progressive relaxation training*. Champaign, IL: Research Press.

Chan, D., & Woollacott, M. (2007). Effects of level of meditation experience on attentional focus: Is the efficiency of executive or orientation networks improved? *Journal of Alternative and Complementary Medicine, 13*(6), 651–657.

Hardt, J. V., & Kamiya, J. (1978). Anxiety change through electroencephalographic alpha feedback seen only in high anxiety subjects. *Science, 201*(4350), 79–81.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research. Brain Research Reviews, 29*(2–3), 169–195.

Kozasa, E. H., Sato, J. R., Lacerda, S. S., Barreiros, M. A., Radvany, J., Russell, T. A., et al. (2012). Meditation training increases brain efficiency in an attention task. *Neuroimage, 59*(1), 745–749.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: Years after. *Annual Review of Neuroscience, 35*, 71–89.

Posner, M. I., Rothbart, M. K., Sheese, B. E., & Tang, Y. (2007). The anterior cingulate gyrus and the mechanism of self-regulation. *Cognitive, Affective, & Behavioral Neuroscience, 7*(4), 391–395.

Ramos-Loyo, J., Gonzalez-Garrido, A. A., Amezcua, C., & Guevara, M. A. (2004). Relationship between resting alpha activity and the ERPs obtained during a highly demanding selective attention task. *International Journal of Psychophysiology, 54*(3), 251–262.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–661.

Takahashi, T., Murata, T., Hamada, T., Omori, M., Kosaka, H., Kikuchi, M., et al. (2005). Changes in EEG and autonomic nervous activity during meditation and their association with personality traits. *International Journal of Psychophysiology, 55*(2), 199–207.

Tang, Y. Y., Lu, Q., Geng, X., Stein, E. A., Yang, Y., & Posner, M. I. (2010). Short-term meditation induces white matter changes in the anterior cingulate. *Proceedings of the National Academy of Sciences USA, 107*(35), 15649–15652.

Tang, Y. Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., et al. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. *Proceedings of the National Academy of Sciences USA, 106*(22), 8865–8870.

Tang, Y. Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., et al. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences USA, 104*(43), 17152–17156.

Tang, Y. Y., & Posner, M. I. (2009). Attention training and attention state training. *Trends in Cognitive Sciences, 13*(5), 222–227.

Tang, Y. Y., Rothbart, M. K., & Posner, M. I. (2012). Neural correlates of establishing, maintaining, and switching brain states. *Trends in Cognitive Sciences, 16*(6), 330–337.

Travis, F. T. (1991). Eyes open and TM EEG patterns after one and after eight years of TM practice. *Psychophysiology, 28*, 58.

van der Hiele, K., Bollen, E. L., Vein, A. A., Reijntjes, R. H., Westendorp, R. G., van Buchem, M. A., et al. (2008). EEG markers of future cognitive performance in the elderly. *Journal of Clinical Neurophysiology, 25*(2), 83–89.

West, R., & Bell, M. A. (1997). Stroop color-word interference and electroencephalogram activation: Evidence for age-related decline of the anterior attention system. *Neuropsychology, 11*(3), 421–427.