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Improving spatial abilities through mindfulness: Effects on the mental rotation task

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ABSTRACT

In this study, we demonstrate a previously unknown finding that mindful learning can improve an individual's spatial cognition without regard to gender differences. Thirty-two volunteers participated in the experiment. Baselines for spatial ability were first measured for the reaction time on the mental rotation task. Next, the participants were randomly assigned to either a mindful or mindless learning condition. After learning, the mental rotation task showed that those in the mindful learning condition responded faster than those in the mindless learning condition. This study provides promising evidence for applying mindful learning to education.

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1. Introduction

Whenever learning a new skill or faced with a new issue, we are predisposed to using the same problem-solving methods that we have used in the past. These mind-sets may, to some extent, allow us to solve certain new problems. However, they may also constrain our thinking (Langer, 2000) because we are likely to equate the new issue to the old one. Previous research on the Einstellung effect has clearly shown that when solving new problems, people are easily trapped into a rigid and limited mind-set by using their old problem-solving pattern(s) and ignoring other simpler and better solutions (Hoffman, Burke, & Maier, 1963; Luchins, 1942). Mind-sets are also widely manifested in our attitudes towards certain social issues such as discrimination towards female employees (Lane & Piercy, 2003; Simpson, 1997) or automatic-stereotypical behavior towards the old and the weak (Bargh, Chen, & Burrows, 1996; Brewer, 1988). In the past several decades we have recognized the counterproductive consequences that mind-sets produce and thus the use of mindful learning and thinking has been increasingly encouraged and used more and more often. Before examining the usefulness of mindful learning, it is necessary to define what mindfulness is and to briefly review the recent related research. Langer and her colleagues (Bondner & Langer, 2001; Langer & Piper, 1987) characterized mindfulness as: (1) the sensitivity to the surrounding environment, (2) the easy acceptance of new and unfamiliar things, (3) the capability to think about an issue from different perspectives, and (4) the creative engagement in categorization. The opposite of mindfulness is mindlessness: a lack of active involvement in thinking.

Ever since the theory of mindfulness was first proposed, a great number of studies, most typically studies done in the fields of clinical psychology and social cognition intervention, have focused on the application of mindfulness. In clinical settings, it has been found that Mindfulness-based Cognitive Therapy (MBCT) (Segal, Williams, & Teasdale, 2002), which is a marriage of mindful learning and traditional cognitive therapy, has great merit in treating people with depression or anxiety (Kuyken et al., 2008; Ma & Teasdale, 2004). Mindfulness also functions in changing an individuals' social cognition as well as in tempering one's emotions. The research results of Langer, Bashner, and Chanowitz (1985) showed that the participants,

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who were trained to think mindfully, primarily thought of the disabled children as specially ‘‘abled’’ rather than incapable. In Djikic, Langer and Stapleton’s (2008) experiment, people who scored at a high level of mindfulness in a picture categorization task, walked quickly, which predicted a reduced level of stereotype-activated behaviors.

To our knowledge, there is ample evidence demonstrating the profound impact in mindfulness on many areas except for the field of spatial cognition. Thus, the focus of this study was to examine whether people’s spatial cognition could be improved through mindful learning. Specifically, we choose the mental rotation task (MRT), which has been identified as an important indicator of spatial ability (Carroll, 1993; Lohman, 1988).

The MRT is a task that typically shows gender differences, in which males’ performance is better than females’ (e.g. Masters & Sanders, 1993). It is used to examine an individual’s spatial cognition by asking the person to determine whether the two pictures presented are ‘‘identical’’ or ‘‘mirroring’’ (Masters & Sanders, 1993; Shepard & Metzler, 1971). The seminal work by Shepard and Metzler has shown that the reaction time (RT) in this task was a linearly increasing function of the rotated angle (from 0° to 180°). In Bethell-Fox and Shepard’s (1988) study, the RT was positively correlated with the complexity of presenting stimuli. However, after people became familiar with the complex stimuli, the RT no longer differed significantly with varying degrees of stimuli’s complexity, but differed when the time was linearly increasing along with the stimuli’s rotated angle. Khooshabeh and Hegarty (2010) also reported that individuals who performed on the MRT were more likely to have employed a holistic strategy one rather than an analytic one.

In summary, the present study examines whether people with either a mindful or a mindless learning condition differed in their performance on the MRT. Our hypothesis was that the participants’ performance on the MRT in the mindful learning condition would be significantly better than those in the mindless one, for mindful learning would induce the participants to apply a holistic strategy. We also predicted that female performance would be less proficient than male performance under both conditions on the MRT.

2. Material and methods

2.1. Participants

Thirty-two students were recruited voluntarily from Nanjing University by advertisement. All of them were right-handed and none had ever participated in any MRT task before.

2.2. Design

We used a 2 (mindfulness or mindlessness) × 2 (male or female) factorial design. As we were concerned that the students’ spatial ability was highly diverse (Kali & Orion, 1996), we collected the data for RT on the MRT before learning as the baseline of the participants’ spatial ability. The dependent variable was the RT on the MRT after learning.

2.3. Materials

The whole experiment was displayed on a 19″ Lenovo LCD screen using *E*-prime. The computer was located approximately 50 cm in front of the participants, resulting in a visual angle of approximately 5°.

2.3.1. Material for mindful/mindless learning

Previous studies indicated that using different wording to introduce an item could stimulate either a mindful or mindless state (Langer & Piper, 1987). The mindfulness material was created to produce a situation in which the participants could attend to a familiar situation from a different perspective in order to break the mind-set and think out of the box (Bondner & Langer, 2001; Langer & Piper, 1987) (see Appendix 1).

The mindful or mindless learning materials were centered on the screen. The participants were required to answer every question within a limited time and to record their answers in the answer sheet. If the participants still had time left after they completed their answers, they were instructed to press the key of ‘‘q’’ to enter into the next question.

2.3.2. Materials for the mental rotation task

We selected the 20° and 120° stimuli rotated from the original pictures on an *x*, *y* or *z* axis from the Shepard and Metzler’s (1971) classical experiment (see Fig. 1). As soon as the participants decided that the two pictures displayed were congruent in their shape, they were instructed to press ‘‘f’’, or if they determined that one picture was mirror-rotated from the other, they were instructed to press ‘‘j’’. The stimuli were classified into three categories: the original–original (constructed by two original items), the mirrored–mirrored (constructed by two mirrored items) and the original–mirrored (constructed by both types of items). The original–original and mirrored–mirrored category both contained 15 trials, including three trials (pictures rotated with 20° and 120° within the same axis) and 12 trials (the combination of four pairs of the two pictures with four rotated angle pairs (20°–20°,120°–120°, 20°–120°,120°–20°) and three rotated axis pairs (*x*–*y*, *x*–*z*, *y*–*z*)). The original–mirrored categories contained 36 trials consisting of the combination of four rotated angle pairs and nine rotated axis pairs (*x*–*x*, *x*–*y*, *x*–*z*, *y*–*x*, *y*–*y*, *y*–*z*, *z*–*x*, *z*–*y*, *z*–*z*).

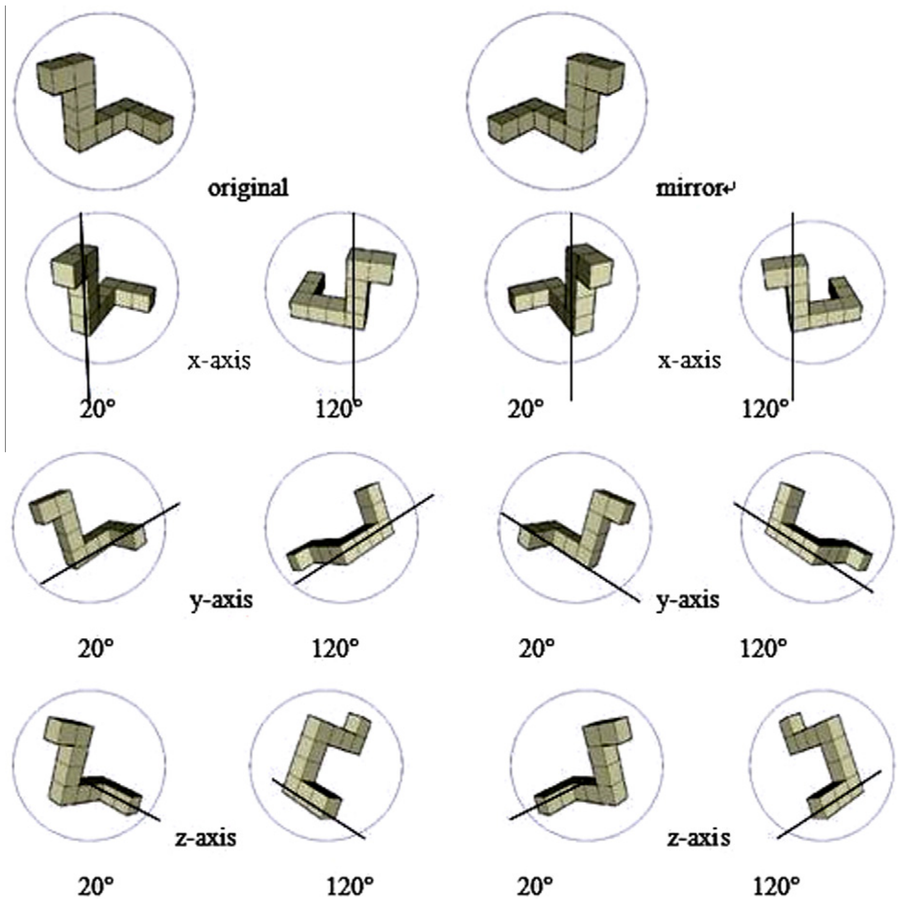

Fig. 1. Examples of mental rotation task in this experiment. The left panel is the original stimulus rotated from *x*, *y*, *z* axis with 20° and 120°; the right panel is the mirror stimulus rotated from *x*, *y*, *z* axis with 20° and 120°.

Each trial began with the fixation point "+". Two circular pictures that contained the stimuli were then simultaneously centered on the left and right panels of the white screen. The diameter of the circle was 5.5 cm, and the distance between the centers of the two circles was 13 cm. The screen could not jump into the next trial until the participants had pressed either the response key "f" or "j".

2.4. Procedure

The participants were informed they were involved in a pattern judgment task and to answer several questions. They were allowed to practice with feedback about their RT and accuracy and expected to complete the tasks accurately and quickly. After they had completed 66 trials displayed randomly without feedback and had had a 2-min break, they were presented with either mindful or mindless learning material on the screen. The participants had to record their answers on the answer sheet. They had 3 min to rest before they worked on the MRT again which shared the identical features with the MRT given at the beginning.

3. Result

We analyzed the data with software SPSS17.0, using a significance level of .05.

The analysis of covariance (ANCOVA) revealed that the baseline on the MRT significantly affected the RT after learning [$F(1, 27) = 92.07$, $p < .001$] and that no interaction was found between gender and RT in first part. These findings suggested that it was reliable to apply an analysis of covariance to this experimental data and necessary to set the baseline of the participants' spatial ability as a covariate variable. Two learning operations had a significant main effect on the RT after learning [$F(1, 27) = 5.15$, $p < .05$, $\eta_p^2 = .16$, $M_{\text{mindfulness}} = 3179.63$ ms, $SD = 1683.13$ ms; $M_{\text{mindlessness}} = 3280.27$ ms, $SD = 1826.63$ ms]. There was no main effect on gender [$F(1, 27) = .51$, $M_{\text{males}} = 3353.86$ ms, $SD = 1697.21$ ms; $M_{\text{females}} = 3106.03$ ms,

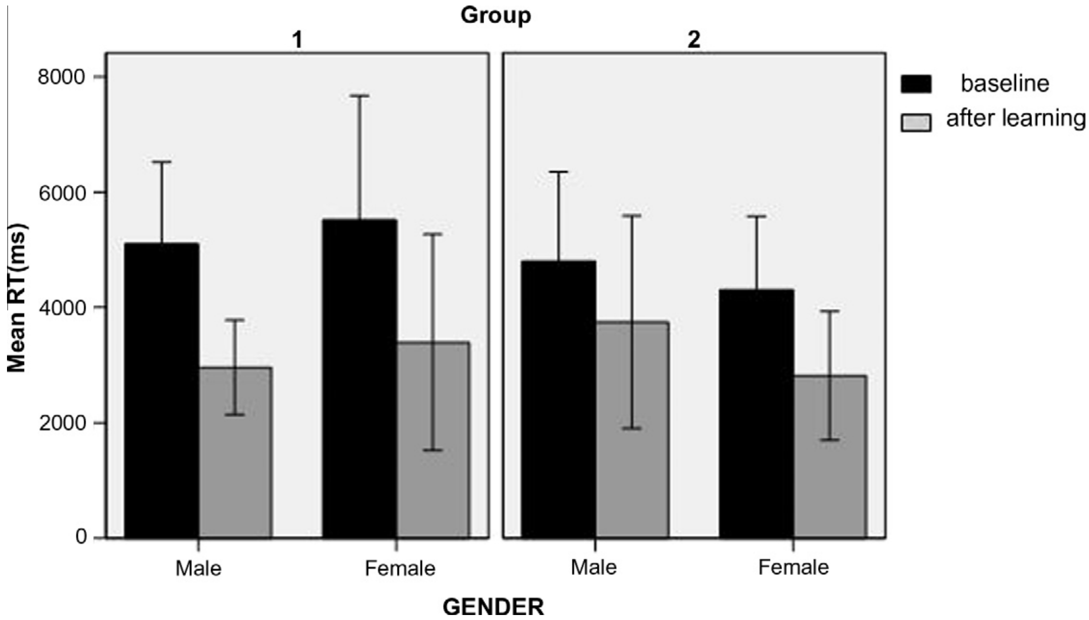

Fig. 2. Mean Reaction Time (RT) as a function of gender and experimental condition in the baseline and after learning. Error bars indicate 95% confidence intervals.

SD = 1805.99 ms]. No interaction was found between gender and learning condition [$F(1, 27) = 1.08$]. Fig. 2 shows the RT on the MRT before and after learning, separated into categories of male and female, with different learning conditions.

4. Discussion

As hypothesized, mindfulness, if experimentally activated, can reduce people's RT on the MRT, which indicates that mindful learning can positively influence an individual's spatial cognition. The results also showed that all the participants responded faster after mindful or mindless learning than before learning, except for one male in the mindless learning condition. The progress that most participants made on the MRT in the second round might be explained by practice effect. It, however, affected the participants' RT on both learning conditions; therefore we took it into account and manipulated it as covariance when analyzing the data. It is likely the one case where the RT of 73 ms after the mindless learning condition was greater than it was before was due to the fact that participants attended more to the accuracy of the response when doing the MRT in the second round than in the first round (the correct rate was from 67%d to 86%).

Several possible mechanisms can explain the MRT improvement after mindfulness training. With high likelihood, people in the mindfulness and mindlessness group employ different thinking strategies after training. In Bethell-Fox and Shepard's (1988) experiment, participants responded to the MRT faster in the test after the MRT training. Thus, Bethell-Fox and Shepard suggested that individuals process the stimuli from a holistic perspective. In the present study, we did not require participants to practice the same tasks again and again; instead, they learned the material either mindfully or mindlessly. The progress that participants made in the mindfulness group was greater than the progress made by those in the mindless group, suggesting that mindful learning condition might motivate the participants to contemplate the tasks from holistic perspective.

Secondly, mindfulness state resembles the concept of "creativity" in many aspects (Langer & Piper, 1987). However, their distinction is not our interest in this study, as to our knowledge, no empirically-validated studies have been done to assess creativity successfully. Like the mindfulness training in Langer and Pipe's study, the mindfulness training in this study can be interpret as training creativity, facilitating flexible thought and benefiting cognition. Therefore, this might be another explanation of the relation between mindfulness and cognition enhancement.

Furthermore, as mindfulness training can reduce participants' fatigue, participants are likely to focus on the cognitive task more attentively than they are after mindlessness training (Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). The aim of the mindfulness training task in this study was to elicit participants' active involvement in thinking. Thus, those people who were assigned to the mindfulness group encoded and retrieved spatial information from working memory more quickly and accurately. However, after completing mindlessness task, the participants might be less active and feel boring and fatigue. Therefore, participants in the mindfulness group responded to the task more quickly than those in mindlessness group.

The results of this study indicate that the RT of males and females did not differ significantly after the intervention, which was inconsistent with our hypothesis and with other previous studies (Masters & Sanders, 1993; Terlecki, Newcombe, &

Little, 2008). In reference to the other studies which reported a gender difference on the MRT, we found that when the participants were required to fulfill the task in a limited amount of time and were instructed to record the raw score of their responses, the performance of the male participants was significantly better than that of the females. However, when the participants were asked to respond without a time limit and were told to record the ratio score of their performance, gender differences faded away (Goldstein, Haldane, & Mitchell, 1990). Stumpf (1993) also suggested that, the varying degrees of complexity of the MRT affected gender differences. Specifically, according to Shepard and Metzler's (1971) research, the participants' RT was a linear function of the stimuli's rotated angle (from 0° to 180°), whereby the complexity was also increased when the rotation angle became greater. Thus, the stimuli which were rotated 180° were much more complex than those rotated 90°. In Stumf's experiment, when the rotation angle of the stimuli was 90°, there was no gender difference, whereas when the rotation angle was 180°, males responded significantly faster than females. Therefore, the gender difference on the MRT depends on the complexity of the stimuli. In this experiment, the participants could respond on the MRT without a time limit, and the feedback in the practice consisted of the correct rate rather than the raw score. In addition, the difference between two pictures presented in every trial was either 0° or 100°, which were closer to the condition of 90° in Stumf's experiment. Based on the empirical evidence provided by the previous studies, males and females were not expected to differ on their MRT scores.

Furthermore, the insignificance of gender on the improvement of the MRT might be due to the insignificant difference of gender on mindful and mindless learning. As none of prior mindfulness/mindlessness studies included gender as an independent variable and reported gender difference in the result (e.g. Djikic et al., 2008), the difference of spatial cognition improvement between mindfulness training and mindlessness training could not demonstrate a difference on gender.

The MRT, as a crucial element in the spatial ability test, has been associated with success in many courses of study. For example the score on the MRT is highly correlated with the successful performance of mathematics and other scientific disciplines (Delgado & Prieto, 2004). Because one of the potential benefits of mindful learning is that it can be developed whenever and wherever wanted, we strongly recommend that mindful learning be introduced into elementary and secondary school education. This will not only facilitate students' out-of-the-box thinking and produce critical thinking towards certain issues, but it is also likely to improve students' spatial ability and thereby nurture their scientific performance.

Future study might explore the effect of long-term mindfulness training. For example, instead of one session of mindfulness training, participants could be required to attend one or two sessions per week for more than 3 months, on people's spatial as well as social cognition instead of one session. In addition, other spatial cognition testing material such as the Uniformed Field of View Task (UFOV) (Edwards et al., 2005) could be used to explore to what extent mindful learning facilitates individual transfer learning. We hypothesize that, mindful learning will be beneficial for improving an individual's performance on spatial cognition tasks as well as on the MRT. This is especially true for long-term performance, since mindful learning addresses the process by which people come to a resolution rather than simply memorizing the results. Additionally, future studies can also explore whether or not mindful learning also improves performance in the fields of memory, language or other cognitive areas.

5. Conclusions

In conclusion, this experiment demonstrated that individuals greatly improved their MRT performance through mindful learning with no significant differences as a result of gender. Future studies could investigate whether or not mindful learning is helpful for transfer study and could also explore to a deeper extent the relationship between mindfulness and memory or language. The application of mindful learning to the realm of education is quite promising.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.concog.2011.02.004.

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