CHAPTER 6

Mindfulness Applications in Education

Abstract Attention is indispensable to school performance and daily life. However, almost 50% of the time we are awake, our mind is wandering. We are not 100% focused on what we are doing in each moment. This chapter focuses on translational work of mindfulness meditation in cognitive and learning ability, as well as in education outcomes. I will take several core cognitive capacities, including attention, conflict resolution, creativity, school test scores, and learning ability, as examples to demonstrate how mindfulness affects each of these domains and its applications in education.

Keywords Conflict resolution · Creativity · Implicit learning · Explicit learning

Attention

As described in Chap. 2, attention often involves alerting, orienting, and executive control attention (conflict resolution) networks (Petersen and Posner 2012). Studies have shown that attention benefits from mindfulness training, especially in executive and alerting attention functions. For example, in a randomized study, few hours of mindfulness meditation/IBMT improved executive attention as measured by the Attention Network Test (ANT) compared to relaxation training (RT). However, this dosage of mindfulness practice does not improve alerting or orienting attention (Tang et al. 2007). Longer IBMT practice (10 h within 1 month) does induce

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significant improvement in both alerting and executive attention in longitudinal studies compared to relaxation control (Tang 2009). In contrast, 8 weeks of mindfulness meditation/MBSR does not improve measures of sustained (alerting) attention in a continuous performance task, but did show some improvement in orienting. Enhanced orienting using other experimental paradigms was also reported in some cross-sectional studies using longer periods (3 months or more) of mindfulness training; however, it should be noted that this design has methodological issues and precludes causal attribution. Although we do not know whether the differences in these studies are due to the type of training, stage of training, type of control, or other factors, the randomized design with an active control is very important to prove the effectiveness of any mindfulness practice (Hölzel et al. 2011; Tang et al. 2015).

Learning a skill often has three phases: a cognitive, an associative, and an automatic phase. Studies have shown that different learning phases recruit different brain regions and networks. For example, the cognitive phase involves the ACC and other cortical regions; the associative phase involves (ACC to) the hippocampus and other areas, and the automatic phase involves the striatum and other areas. We already know that attention is crucial for the storage and retrieval of memories, but little is known about the pathways by which attention interacts with the hippocampus, a brain region involved in learning new information. In recent years we have begun to understand the brain mechanisms by which attention controls what is learned and remembered. A brain network connecting the ACC to the hippocampus appears to be important for the registration of new learning and provides a mechanism for how attention influences learning in educational setting. These findings also suggest the potential of improving education outcomes through training attention (Tang 2017; Posner et al. 2013; Posner and Rothbart 2014).

People with ADHD have problems maintaining attention over prolonged periods of time, have difficulty in holding goals and plans in mind, and have difficulty inhibiting a pre-potent response. Consequently, this disorder is characterized by symptoms of inattention, impulsivity, and hyperactivity, and has an impact on brain function and structure. It also causes academic and social problems not just for young children, but also for college students and adults. Mindfulness meditation has been shown to improve attention and self-control, and could ameliorate core ADHD symptoms. In a recent meta-analysis on the effectiveness of mindfulness on ADHD, results suggest the possible benefits of mindfulness in reducing symptoms of ADHD (Cairncross and Miller 2016). Therefore, mindfulness meditation could help children and adults with ADHD and learning difficulty, subsequently improve education outcomes (Schoenberg et al. 2014; Tang et al. 2015). It should be noted that treatment of ADHD symptoms using mindfulness at least two strategies should be considered: one is to improve attention ability to ameliorate attention deficit; another is to reduce impulsivity and hyperactivity. Approaching these two symptoms of ADHD may serve to re-balance attention capacity (Tang and Tang 2015) (see more in Chap. 7).

Conflict Resolution

Resolving conflict is a pivotal attention and self-control ability for human adaptation and survival. It is also important in decision-making and problem solving in school, work, and daily life. Our previous randomized research showed that short-term IBMT (five sessions, 20 min per session) improves the efficiency to resolve conflict (executive attention) in a flanker task (Tang et al. 2007). Stroop interference has often been used as the gold standard for assessing conflict resolution; it refers to the longer time that people take to name the ink color of a color-word when the ink color and printed color-word are incongruent (e.g., "RED" in blue ink, meaning the "conflict condition") as compared to congruent (e.g., "RED" in red). Therefore, it would be important to see if mindfulness can also have a positive effect on Stroop performance. One study reported that conflict in the Stroop task is influenced by long-term meditation practice, but another study failed to find the same effects of mindfulness meditation. Recently, some studies showed better performance on Stroop task in meditators compared to a waiting list control. However, these studies were not randomized and did not have an active control, and therefore could not provide a convincing conclusion on causality (Fan et al. 2015; Tang et al. 2015).

To examine whether a few hours of mindfulness practice could improve Stroop effects, we recruited undergraduates without any training experiences and randomly assigned them into an experimental (IBMT) group and an active control group (relaxation training), each of whom attended five sessions of IBMT or relaxation training, respectively. We found that compared to the pre-training scores, both IBMT and relaxation groups showed significant reduction in the post-training reaction time for congruent, incongruent, and neutral conditions. Conflict scores refer to the difference between congruent and incongruent conditions. The pre- versus post-difference in conflict reaction-time scores was significant only for IBMT group. Prior to training, the IBMT and relaxation groups did not differ in reaction times and accuracy scores. However, after training, compared to the relaxation group, the IBMT group demonstrated superior performance in the Stroop task, as indicated by significantly faster reaction times in the congruent, incongruent, and neutral conditions, as well as smaller conflict scores. For accuracy analysis, no significant differences were found between two groups in each session, nor between two sessions within each group. These results suggested that less reaction time in the post session was not due to participants responding less carefully (Fan et al. 2014, 2015).

Creativity

Working memory is the ability to maintain and manipulate information in one's mind while ignoring irrelevant distractions, and it plays a key role in education and daily life. Creativity (creative performance) is also essential to the development and advancement of human civilization and plays a crucial role in our society and life. Therefore, researchers across various disciplines have a growing interest in the potential of fostering creativity through education or/and training.

The Torrance Test of Creative Thinking (TTCT) is one of the most widely used tests of creativity (creative performance) that measures divergent thinking. The TTCT has four subscales:

1. Fluency: The number of relevant responses to the questions, which shows the ability to produce and consider many alternatives.
2. Flexibility: The (total) number of categories that answers are assigned based on a criteria table or an almost equivalent judgment, which shows the ability to produce responses from a wide perspective.
3. Originality: The number of statistically infrequent ideas, which shows the ability to produce ideas that differ from others.
4. Elaboration: The ability to produce ideas in detail (Ding et al. 2014a).

We randomly assigned healthy college students into IBMT group or RT group. Participants either completed the IBMT or RT of 30 min/day for a week. Before training, there was no significant difference in TTCT between the two groups. However, we found a significant group (IBMT vs. RT) × session (pre-training vs. post-training) interaction effect and a session (pre-training vs. post-training) main effect for TTCT. The IBMT group obtained significantly better scores in TTCT percent change from pre-training to post-training in comparison with the RT group. These results indicated that short-term IBMT can produce a better creative performance than the same amount of RT (Ding et al. 2014b).

The improvement of creativity may be caused by a variety of psychological factors such as intelligence, attention, and mood states with regard to the influence on creative fluency and originality. We thus applied the Positive and Negative Affect Schedule (PANAS) to measure positive affect (PA) and negative affect (NA) along with the TTCT before and after training. The PA score (assessed by PA subscale) increased significantly and the NA score (by NA subscale) decreased significantly after few hours of IBMT compared to RT. We concluded that short-term IBMT yielded a better emotion state than RT. Thus, these results are consistent with our hypotheses that emotional improvement may be one way that TTCT scores are changed after short-term meditation (Ding et al. 2014a).

Further brain-imaging work of creative performance using insightful problem solving showed that in comparison with the same amount of RT, 5 h of IBMT induced greater brain activity, mainly in the cingulate, insula, putamen, inferior and middle frontal gyrus, the inferior parietal lobule (IPL), and the superior temporal gyrus (STG). Based on prior research, these brain activity patterns may suggest the following functions: the cingulate is involved in detecting conflict and breaking mental set; the inferior and middle frontal gyrus play an important role in restructuring the representation of the problem; the insula, IPL, and STG are associated with error detection, problem understanding, or general attentive control; and the putamen is activated by an "aha" feeling (Ding et al. 2015).

It should be noted that mindfulness meditation has various forms, but two styles are commonly studied. One is focused attention meditation, which requires the voluntary focus of attention on an object such as breathing. Another is open-monitoring meditation, which involves nonreactive awareness of the momentary experience (Lutz et al. 2008). Studies showed that different styles of mindfulness meditation may impact different aspects of cognitive performance such as creativity. For example, one study investigated the impact of focused attention and open-monitoring meditation on creativity tasks tapping into convergent and divergent thinking (Colzato et al. 2012; Lippelt et al. 2014). Results showed that open-monitoring meditation promotes divergent thinking (allowing the generation of many new ideas), whereas focused attention meditation does not sustain convergent thinking (generating one possible solution to a particular problem). Consistent with the literature, our studies using brief IBMT also show significant improvement in diverse creative performance because IBMT is one form of open-monitoring meditation. These findings may suggest that not all types of meditation have the same effect on creative performance, but the effect is due to different attention and control processes (Tang 2017).

School Performance

Improved attention and self-control appear to have a beneficial effect on learning in educational areas such as literacy and numeracy. In one study, higher self-control in temperament scales was associated with better school performance in many participants, while the enhanced executive attention network was related to improved mathematics performance in particular (Checa and Rueda 2011). However, there was no evidence that brief meditation training improves academic performance in school. Therefore, the following studies were conducted to test this hypothesis.

Two hundreds and eight students (aged 13–18 years) were recruited from middle and high school and randomly assigned to either IBMT or RT control groups (104 students per group). They received 6 weeks of IBMT or RT intervention (~20 min per day from Monday to Friday, totaling 10 h) during school lunch breaks prior to their yearly final examinations (Tang et al. 2014). The IBMT intervention used for this group involved body relaxation, mental imagery, and mindfulness training. The IBMT method stresses making no effort, or less effort, to control one's thoughts and promotes a state of restful alertness that allows a high degree of awareness of one's body, mind, and external instructions. RT involved the relaxation of different muscle groups over the face, head, shoulders, arms, legs, chest, back, and abdomen. With eyes closed and in a sequential pattern, one concentrates on the sensation of relaxation, such as the feelings of warmth and heaviness (Tang et al. 2007).

Self-control involves the important components of attention control and emotion regulation. We measured the efficiency of attention networks using ANT; the mood state using the POMS, the intelligence scores using the Raven's standard progressive matrix, and the self-report stress using perceived stress scale (PSS). All of these are frequently used measures of performance or subjective experience. The school provided information of the official grades obtained at the end of the academic year for each student. Academic performance grades were obtained for Literacy (Chinese), Mathematics, and Second language (English).

Before training, the two groups of IBMT and RT did not show any significant difference in all the assays and grade scores. After training, we examined the training effect on ANT, Raven's Matrices, POMS, PSS and academic grade between IBMT and RT groups, and found 10 h of IBMT significantly improved both executive and alerting attention, replicating our previous results, and indicating better self-control and attention ability. However, orienting attention showed only marginally significant improvement following IBMT. The same amount of RT also improved attention efficiency after practice but did not show significance. We also tested whether intelligence was improved after training. Results before and after training showed a significant improvement in Raven scores indicating that short-term IBMT can improve intelligence, but no significant improvement following RT was detected (Tang et al. 2014).

Since the brain circuits of executive attention and self-control overlap in midline ACC, if the efficiency of executive attention is improved, we expect better self-control of emotion. After training, there were significant differences in the IBMT group (but not the RT group) in the POMS scales: anger–hostility, depression–dejection, and fatigue–inertia, tension–anxiety, and vigor–activity. These results showed that short-term IBMT can enhance positive moods and reduce negative ones. Meanwhile, PSS also favored the IBMT group (not the RT group) after training. The academic achievement indexed by the final mean of grades in Literacy, Mathematics, and Second language was also significantly improved following IBMT intervention (Tang et al. 2014).

Attention control and emotion regulation are important components of self-control. In our previous work, five sessions of IBMT (~2 h) significantly improved executive attention, as well as emotion in POMS, and marginally significantly improvement in Raven scores. In the present study, we used diverse assays including ANT, POMS, Raven's Matrix, and PSS to measure self-regulation ability and found that 10 h of IBMT intervention can improve attention, emotion, and Raven scores. Meanwhile, we also found improvement in the academic performance in scores of Literacy, Mathematics, and Second Language learning (Tang et al. 2014).

Studies have shown that attention is crucial for the storage and retrieval of memories, and individual differences in self-control make a major difference in school and in life outcomes. Multiple studies have shown that explicit learning (e.g., memorizing for recall) has the goal of learning the material so that it can be brought to the mind consciously, and being attentive at the time of learning is also crucial for many aspects of school education. Learning Literacy, Mathematics, and Second Language requires heavy attention to memorize the subject contents and reasoning relationship, and also requires self-control to maintain better positive emotion and less stress for an optimal learning environment. The improved attention and emotion following IBMT intervention may support effective learning at school and thus lead to better academic achievement in the subject test scores (Tang 2017).

Further, improving self-control also has a broad impact on learning difficulty and mental disorders. For example, self-control deficits are often related to ADHD, mood disturbances, school failure, addiction, and antisocial behavior. In this study we found improved IQ following 10 h of IBMT, compared to our previous work that did not find IQ changes after two hours of training, these results may suggest that the difference is due to the length of training.

The current results with the ANT indicated that 10 h of IBMT improves the functioning of both executive and alerting attention network, whereas ~2 h of IBMT only improved executive attention, indicating the dose-dependent effects of IBMT practice. Although our study did not examine brain activity, previous work suggests that executive attention is an important mechanism for self-control in cognition and emotion. Studies designed to improve executive attention (self-control) have found an important node of the attention network in the ACC. We speculate that the improved activation or/and connectivity of this self-control network following IBMT is an important neural mechanism supporting these changes in behavior and academic performance. Future research should explore the relationship between training length and improvement of learning school subjects, the lasting effects of training, and the generalization of school subjects (Tang et al. 2014; Tang 2017).

In sum, these results suggest that brief mindfulness training can be integrated into the current curriculum in our school system to improve academic performance in different subjects and other positive behaviors (Tang 2009, 2017).

Implicit Learning

While explicit learning and memory are central to success in school, implicit learning also has important influences on our everyday functioning and overall health, such as language learning, environmental adaptation, and developing habits and aversions, since these processes often occur without goal-directed intention or conscious awareness. As discussed earlier, mindfulness training improves explicit learning. Does mindfulness affect implicit learning: the type of learning that can take place without the intent to learn or the awareness of what has been learned? Using an implicit learning task—implicit probabilistic sequence learning (IPSL)—one study examined the hypothesis that higher dispositional mindfulness is associated with reduced implicit learning. In this sequence learning task, the first triplet indicates a high-probability triplet and the second triplet indicates a low-probability triplet. Participants view sequences of events and are asked to respond to certain targets. The goal is for participants to learn the sequence and regularity implicitly (Stillman et al. 2014).

Dispositional mindfulness is associated with better performance on a wide range of cognitive tasks such as sustained attention and inhibitory control tasks, which require conscious control mainly through lateral prefrontal regions of the brain. Studies of IPSL highlight the role of subcortical structures, especially the striatum (not PFC), for this type of implicit learning. Importantly, IPSL is impaired by the engagement of frontal control processes. For example, IPSL improves following inhibitory theta burst stimulation in the dorsolateral PFC.

In two experiments, healthy college students or older adults completed the Mindful Attention Awareness Scale (MAAS) that measures dispositional mindfulness, and completed the IPSL to measure implicit learning ability. Consistent with authors' predictions, there was a negative correlation between mindfulness and implicit learning scores (the higher the MAAS score, the lower the implicit learning score). These findings may suggest that there are tradeoffs to mindfulness if the practice involves effortful process, such that it benefits some domains of functioning but not implicit learning due to possibly opposite brain mechanisms that are involved (Stillman et al. 2014).

If one form of mindfulness meditation mainly uses less effort or effortlessness, what will happen to implicit learning? IBMT originates from ancient Eastern contemplative traditions, including traditional Chinese medicine and Zen. As we describe earlier, the training stresses no effort or less effort to control thoughts and the achievement of a state of restful alertness that allows a high degree of awareness and balance of the body, mind, and environment. A number of randomized clinical trials indicate that IBMT improves attention and self-control and induces neuroplasticity through interaction between the CNS and ANS. To test our hypothesis that mindfulness with less effort could improve implicit learning, we recruited 30 healthy adults (mean age: 55 years) and randomly assigned them into either the IBMT or physical exercise groups. After 10 years of practice (~ 1 h per day), we found better implicit learning in IBMT group compared to the exercise group. Furthermore, the IBMT group also showed significantly greater grey matter in the striatum, including the caudate and putamen, which often have reduced grey matter following aging. These results suggest that mindfulness meditation such as IBMT that mainly uses less effort or effortlessness can improve implicit learning ability. In sum, certain mindfulness techniques and practice strategies appear to have positive impact on implicit learning (Tang 2017).

It should be noted that in this chapter, I mainly focus on the mindfulness effects on knowledge-based learning and education outcomes. Since mindfulness improves self-control, it could also help character development such as emotion regulation, persistence, and other virtues and strengths, all of which are important to success in school, professional life, and relationships. Just like a bird has two wings, both knowledge-based learning and character development are all-important in education, in work, and in life.

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