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THE NEUROSCIENCE OF MINDFULNESS MEDITATION

How the Body and Mind Work Together to Change Our Behaviour

Yi-Yuan Tang

The Neuroscience of Mindfulness Meditation

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To my family, for their endless support and love.

Foreword

Toward a Mindful Brain

Yi-Yuan Tang is an expert in this area. As a tenured professor and institute director, he has over 30 years of experience in China to test mindfulness training effects in both healthy and patient populations. Then he came to the U.S. to extend his basic and translational research work in both University of Oregon and Texas Tech University. I have been working with him on mechanisms of mindfulness training on attention and self-control since 2006, and have published over 30 peer-review articles together. We propose mindfulness training as one form of the state training compared to the network training such as computerized working memory program. We also demonstrate mindfulness training improves self-control through at least 3 ways—attention control, emotion regulation and self-awareness.

This book provides both a guide for obtaining a mindful brain and a summary of the evidence that by doing so one may lead a happier and more productive life. Yi-Yuan Tang created a method for training mindfulness—Integrative Body-Mind Training (IBMT), adapted from ancient Chinese medicine, he found significant effects from the brain state achieved within only few hours of practice sessions. He has also been a perceptive student of many other forms of mindfulness training and contemplative traditions.

Following editors' suggestion, this book covers the research and application of mindfulness training in general, rather than IBMT only. For typical readers of this volume with an interest in the practice of mindfulness it might be best to read Chap. 1 and 8 first, before attempting the more complex review of the neuroimaging results and their application to education and health. Chapter 8 provides an inspiring perspective to the authors approach to training mindfulness which may serve to help the reader through the more difficult parts of the volume.

In six brief chapters he summarizes how mindfulness training can improve mental activity and change brain connectivity and bodily processes. Among his major ideas is that mindfulness training can result in improved attention, mood and reduced stress in only 5 sessions of practice and the amount of training is related to the amount of stress reduction. This rapid effect of mindfulness training allows for studies with random assignment to either meditation or a relaxation control and leads to his conclusion that meditation is the cause of the many effects. Many readers will be interested in the improvement in school grades and health that are among the more practical consequences of mindfulness training.

For those more interested in the brain it is impressive that mindfulness can improve aspects of both central and autonomic nervous systems. Magnetic Resonance Imaging is used both to find areas more active following meditation than in controls and improved connectivity between brain areas. Measures of heart rate are used to show how the parasympathetic part of the autonomic nervous system helps produce the meditation state. Yi-Yuan also says that meditation training effectiveness differs among individuals and provides a perspective on who is most likely to benefit.

It is important to recognize that my long association with the author may bias my reading of this volume. However, for those with a scientific interest in mindfulness this seems to me to be a serious and accurate approach to the field. It is not exhaustive but it does summarize important findings, many already published, and provides the helpful perspective of the author.

Michael I. Posner

Acknowledgements

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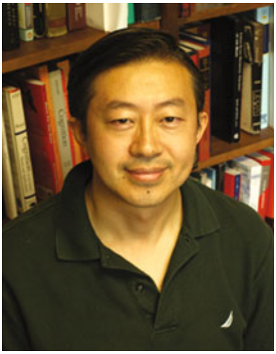

Yi-Yuan Tang is Professor of Psychological Sciences and Internal Medicine, as well as Presidential Endowed Chair in Neuroscience, at Texas Tech University (Lubbock, TX, USA). He is a Fellow of both the Association for Psychological Sciences and the American Psychological Association. He developed mindfulness-based Integrative Body-Mind Training (IBMT)® in China in the 1990s and has trained many adults and children in Asia, North America, and Europe to improve attention, self-control, cognitive performance in school and in the workplace, as well as in health, relationships, and quality of life.

Dr. Tang's basic and translational research has demonstrated the scientific basis for mindfulness training and health, and cognitive benefits following only a few hours of practice. He has published eight books and more than 290 peer-reviewed articles, in scientific journals such as *Nature Reviews Neuroscience*, *Proceedings* *of the National Academy of Sciences*, and *Trends in Cognitive Sciences.* These findings have been reported on in publications such as *Nature* and *Science*, and in popular media including *TIME*, *The New York Times*, BBC, The Press Association, Reuters, and NPR.

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CHAPTER 1

Mindfulness Introduction: From Mind Full to Mindful

Abstract This chapter aims to clarify what mindfulness meditation is, and to introduce the emerging field of Mindfulness Neuroscience, which can help individuals better understand the brain mechanisms underlying mindfulness and other mental states. This chapter will also point out the methodological challenges in the mindfulness field and the possible solutions to these challenges.

Keywords Mindfulness meditation · Mindfulness neuroscience · Integrative Body-Mind training (IBMT)® · Mind-fullness · Mindlessness · Longitudinal studies · Cross-sectional studies · Methodological challenges

Meditation is a form of mental training and encompasses a family of complex practices such as mindfulness meditation, yoga, Tai Chi, and Qigong. Of these practices, mindfulness meditation has received the most attention in psychology and neuroscience research over the past two decades (Tang et al. 2015). Many people use the term "mindfulness," but they often refer to completely different things. Therefore, it may mislead one's fundamental understanding of the concept and consequently, one's practice. In this chapter, I will introduce three states of mind—mind-fullness, mindlessness, and mindfulness—as examples to clarify the term "mindfulness" and to help the readers grasp the essence of mindfulness more easily. In reality, *mindfulness is NOT a concept; instead, it is a direct experience prior to one's conceptualization* per se. Without any personal experience of mindfulness,

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one can only get the partial reflection of that experience, perhaps like a blind man touching only parts of an elephant. However, an experienced teacher or coach can bridge an individual with real mindfulness state and further help the individual stabilize this experience in the brain and body. In one form of mindfulness meditation practice, *Integrative Body-Mind Training (IBMT)®*, we often use this coach-facilitating technique to help novices (Tang et al. 2015; Tang 2009; Tang and Tang 2015b).

Are You Mind-Full or Mindful?

Nowadays, within the overloaded world of information, we are always "online." In other words, we are all *mind-full*: our mind continuously collects endless information consciously or/and unconsciously. We do not have more space or capacity to reorganize and digest this accumulated information, because each moment our mind is thinking or wandering, and receiving or processing information restlessly. *Mind-less* state refers to an automatic and habitual response to external stimuli without conscious awareness involvement, and mind-less state and behavior often happen when our mind is not well-trained. Moreover, mind-full and mind-less states are out of our mind control and running automatically. From the neuroscience perspective, mind-full and mindless states occupy too much of the energy and resources of our brain, which are mainly supported by the default mode network in the midline areas of our brain. In this situation, the mind is not sharp enough to best contribute to our work and life achievements (Tang and Tang 2015a, b).

What is mindfulness? There are many definitions of mindfulness. For example, mindfulness refers to *non-judgmental attention to the present moment* (Kabat-Zinn 1990); another example, "*When we are mindful, we are open to surprise, oriented in the present moment, sensitive to context, and above all, liberated from the tyranny of old mindsets*" (Langer 2014). However, the definition of mindfulness is still in debate because mindfulness itself lies beyond these descriptions. As I pointed out earlier, *mindfulness is NOT a concept; instead, it is a direct experience prior to one's conceptualization* per se. A simple analogy would be: no matter how much you know about an apple, only after you have eaten an apple would you know what it tastes like. Compared to mind-fullness or mindlessness, mindfulness is a direct and present experience that is different from the other two states (Tang et al. 2015). From an experiential perspective, mindfulness is described as: *"When you first become aware of something, there is a fleeting instant of pure awareness just before you conceptualize the* *thing, before you identify it. That flowing, soft-focused moment of awareness is mindfulness"* (Gunaratana 2011). A qualified teacher or coach can help you experience mindfulness state directly (also known as "experiential insight") and then stabilize it. This experience can facilitate your practice significantly. Compared to mind-full and mindless states, mindfulness is a subtle and deep process that can reorganize the overloaded information in an efficient way and thus release your occupied brain resources for attention, self-control, and optimal performance in daily life (Tang and Posner 2013a, 2013b; Tang 2017; Tang et al. 2017a, b).

The Clarification of Mindfulness

One recent perspective divides mindfulness meditation or intervention into: (1) mindfulness-based stress reduction (MBSR) and related group-based mindfulness interventions such as mindfulness-based cognitive therapy (MBCT); and (2) mindfulness-related interventions, such as acceptance and commitment therapy (ACT), dialectical behavior therapy (DBT), cognitive behavioral stress management, and IBMT (Creswell 2017).

However, the confusion is that the phrase "related group-based mindfulness interventions" and the term "mindfulness-related interventions" seem to be the same. Even if the author suggests the difference resides in the "group-based" aspect, many other interventions, including MBSR and MBCT, are also group-based. Furthermore, interventions in the first group are defined as training that foster mindfulness, whereas interventions in the second group are characterized as training that incorporates mindfulness as one component of the program. In reality, this is far from accurate, since MBSR and MBCT also involve multiple components, including mindfulness (Kabat-Zinn 1990; Davidson and Kabat-Zinn 2004; Segal et al. 2002). Therefore, after careful examination of the distinctions made by the author, the major difference between groups one and two seems to be that the former has the term "mindfulness" in the name of the intervention, and hence are categorized as mindfulness-based interventions, but the latter does not. To provide a more thorough understanding, below I outline some of the similarities and differences in these interventions as discussed by leading researchers in the field (Kabat-Zinn 1990; Davidson and Kabat-Zinn 2004; Smith 2004; Segal et al. 2002; Linehan 2014; Tang et al. 2015; Hayes et al. 2016; Tang 2017; Tang et al. 2017c).

MBSR was described as a *"program that focuses on learning how to mindfully attend to body sensations through the use of body scans, gentle* *stretching, and yoga mindfulness exercises, along with discussions and practices geared toward applying mindful awareness to daily life experiences, including dealing with stress"* (Creswell 2017). These descriptions clearly indicate that MBSR has multiple components including mindfulness, yoga exercise, body stretching, group discussion, and other components in the program, just like the second group of mindfulness-related interventions mentioned earlier. Therefore, it does not make sense to characterize only MBSR or MBCT as mindfulness interventions, but exclude other mindfulness interventions that do not have the term "mindfulness" in their names. Consistent with MBSR developer Kabat-Zinn's clarification in his book and later articles, there is no pure mindfulness program, and mindfulness intervention such as MBSR incorporates other techniques (Kabat-Zinn 1990; Davidson et al. 2003; Davidson and Kabat-Zinn 2004). Smith (2004) also pointed out that "MBSR system is an amalgam of mindfulness meditation, concentrative meditation, passive breathing exercises, yoga stretching, and other components." Therefore, mindfulness intervention or training works through an integration of several techniques and components rather than a single technique-mindfulness.

In the same vein, MBCT developers described the training as a program that draws from cognitive behavior therapy (CBT) and traditional mindfulness practices such as MBSR. By definition, MBCT is a psychological intervention for individuals at risk of depressive relapse (Segal et al. 2002). Clearly, MBCT also incorporates other trainings such as CBT and MBSR into its program, and it does not make sense to suggest MBCT is a mindfulness intervention, but other similar programs (e.g., ACT, DBT, IBMT) without the term "mindfulness" are not. This clarification is crucial, since a misunderstanding of what mindfulness interventions are will mislead the research community and general public on mindfulness and its application, and may create confusion or even bias for people who are interested in research and applied work in this field.

Therefore, the name of a mindfulness meditation or intervention with or without the term "mindfulness" should not define the nature of the program. Instead, the exact components and instructions of mindfulness practice are the key to define the program. Moreover, we need to understand that mindfulness methods always include several components and there is no pure "mindfulness" with only a mindfulness component (Davidson and Kabat-Zinn 2004; Smith 2004; Tang et al. 2007; Tang and Tang 2015a, b; Tang 2017; Tang et al. 2017c).

Mindfulness Neuroscience

Several years ago, I, along with my colleague Michael Posner, proposed an emerging new field—Mindfulness Neuroscience—in a special issue of the journal *Social Cognitive and Affective Neuroscience* (*SCAN*). Mindfulness Neuroscience aims to investigate the underlying mechanisms of different mindfulness practices, different stages and different states of practice, as well as different effects of practice over an individual's lifespan. Mindfulness Neuroscience integrates theories and methods from Eastern contemplative traditions, Western psychology and neuroscience, and makes use of brain imaging techniques, physiological measures, behavioral tests, and genetic methods. In Chap. 2, I will discuss brain mechanisms in detail (Tang and Posner 2013a, b).

Methodological Challenges in the Mindfulness Field

To move mindfulness research and application forward, current methodological challenges in the field of mindfulness should be considered (Davidson 2010). Although the number of published articles on mindfulness research has increased significantly, as shown in several meta-analyses by different groups, the methodological quality of many studies is still relatively low. Few are actively controlled longitudinal studies, which compare data from one or more groups at several time points and include an active control condition and random assignment to conditions. In addition, sample sizes are usually small. Most studies were cross-sectional;—they compared data from a group of meditators with data from a waitlist control group of non-meditators matched on various dimensions at one time point. Although a number of cross-sectional studies suggested positive changes associated with meditation, this design precludes causal attribution: it is possible that there are pre-existing differences in the brains of meditators, which might be linked to their interest in meditation, motivation, expectancy, personality, and other factors (Tang et al. 2015).

It is important to control for confounding variables that may influence the outcomes of meditation, so more recent studies have been developed that include active interventions in control groups such as relaxation training, stress management education, or a health enhancement program; these interventions can control for confounding factors such as social interaction with the group and teachers, and the amount of home exercise, physical exercise, and psychoeducation. These studies are therefore better able to extract and delineate the meditation-specific effects. For instance, as shown in recent studies by University of Wisconsin, there are no differences in longitudinal randomized trials comparing MBSR versus an active control —health enhancement program (MacCoon et al. 2012, 2014; Rosenkranz et al. 2013).

As is typical for a young research field, many mindfulness experiments are not yet based on elaborate theories in a rigorous design, and conclusions are often drawn from post hoc interpretations. But I believe that future research must use more longitudinal, randomized, and actively controlled research designs with larger sample sizes to advance the understanding of the mechanisms of mindfulness meditation. Therefore, in this book, I will only include actively controlled longitudinal studies to support our discussion and conclusions. In the next chapter, we will explore the brain mechanisms of mindfulness meditation together.

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CHAPTER 2

Brain Mechanisms of Mindfulness Meditation

Abstract Many brain regions have been reported to be involved in different forms of mindfulness meditation. What is the function of each participating region? Do different forms of mindfulness meditation involve different brain networks? Do different practice stages recruit the same or distinct brain regions while practicing the same mindfulness technique? Does the brain network differ with amount of effort during practice? To answer these questions, I organize this chapter based on the latest neuroscience findings, showing that mindfulness meditation includes at least three components: enhanced attention control, improved emotion regulation, and altered self-awareness. I discuss the brain regions involved in these components respectively, mainly including anterior cingulate cortex (ACC) and adjacent prefrontal cortex, striatum, insula, and default mode network (DMN). I also propose a distinction between *state training* and *network training* to clarify the unique brain networks following mindfulness meditation.

Keywords Attention control · Emotion regulation · Self-awareness · Self-control · State training · Network training · Default mode network · Cognitive behavior therapy (CBT)

Key Components of Mindfulness Meditation

In recent years, more than 500 works on mindfulness meditation have been published annually. Based on the latest neuroscience findings, mindfulness meditation includes at least three components that interact closely to

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constitute a process of *enhanced self-regulation* or self-control: enhanced attention control, improved emotion regulation, and altered self-awareness (Tang et al. 2015; Holzel et al. 2011).

Attention control refers to the persistent focus on an object or target (e.g., breath, sensation) during the mindfulness practice, and often involves alerting, orienting, and executive control attention networks. Attention controlinvolves explicit process with conscious control and effort at the early stage of mindfulness practice, but the advanced meditator can use less effort or engage in an effortless way to maintain the focus and awareness. Moreover, mindfulness practice trains a unique attention toward the present experience, and thus could mitigate negative affective experiences in a nonjudgmental and accepting way (Tang and Tang 2015a, b).

Emotion regulation refers to implicit and explicit strategies that can influence which emotions arise and when, how long they occur, and how these emotions are experienced and expressed. Emotion regulation is needed to handle the experiences of boredom and of negative moods during mindfulness practice. When the practitioner is skillful, positive emotions associated with subjective experience of joy and well-being emerge, which can help sustain attention and the meditative state, thereby supporting mental processes (Tang and Tang 2015b).

Self-awareness often refers to the awareness of "self" as the object of attention (meta-awareness). Meta-awareness is often used to describe the function of being aware of mental processing or processes of consciousness. During mindfulness meditation, we are aware of our own internal bodily state (interoception) and mental (consciousness) state in an equanimous way (Tang et al. 2015), then gradually our self and environment merge or dissolve into one inherent experience. Self-awareness through mindfulness practice can help distance the individual from his/her own thinking and thought processes, which in turn facilitates openness and acceptance of thought, emotion and sensation (Tang et al. 2015; Tang and Tang 2015b). Without meta-awareness of self, we become a part of what we experience such as sensation, emotion, and thoughts. Here, we discuss key brain regions involved in these three components respectively.

Brain Regions Related to Attention Control During Mindfulness

Neuroimaging studies show that the brain regions involved in attention control mainly include the anterior cingulate cortex (ACC), the adjacent medial prefrontal cortex (mPFC), and the striatum/basal ganglia including the nucleus accumbens (NAc), which is also a key brain region in the reward circuit (Petersen and Posner 2012). Similarly, brain systems shown to be activated in the broad construct of self-regulation cover the same ACC, adjacent mPFC, and striatum (Posner et al. 2007). Thus, the overlap of brain regions associated with attention control and self-regulation suggests a neurobiological pathway whereby mindfulness meditation could exert its influences including at least the ACC, mPFC, and striatum (Tang et al. 2015). Importantly, when expert meditator maintains an advanced state such as Jhana using the appropriate amount of effort and attention control, an ecstatic meditation experience with extreme joy and pleasure would occur, suggesting that an optimal attention control could activate the reward system including NAc in the striatum, and the striatum (as the key region of attention control) could further strengthen self-control ability of attention. Studies have also shown more release of neurotransmitter dopamine in the striatum following meditation (Tang et al. 2015).

Usually an individual exerts great effort to meditate in the early stage of practice, and the dorsal lateral PFC and parietal cortex are often involved (Posner et al. 2015; Tang et al. 2015). In contrast, the ACC and striatum mainly participate while one uses less effort. Since meditation tends to reduce mind-wandering or/and task-unrelated thoughts that are associated with midline brain areas including mPFC and posterior cingulate cortex (PCC))/precuneus, which all belong to the default mode network (DMN), meditators who engage more effort have been shown to have stronger deactivation in DMN. This suggests that more effortful meditation requires higher mental effort with increased attention, which seems to be mediated by strong deactivation in DMN and activation in dorsal lateral PFC (Tang et al. 2015).

Brain Regions Related to Emotion Regulation During Mindfulness

Studies have shown that the prefrontal regions of the brain, including the mPFC and ACC, are primarily responsible for the regulation of emotion through the modulation of limbic system activity, while at the same time ensuring that current strategies are consistent with the regulatory goals (Bush et al. 2000). There are different strategies for regulating one's emotions explicitly and implicitly, and each strategy involves shared and distinct neural networks (Gross 2014). Although there are subtle differences among various control strategies, the ACC, mPFC, and limbic regions are consistently involved in the regulation of emotional responses during mindfulness. Particularly, emotion regulation is needed to handle the experiences of boredom and of negative moods during mindfulness practice when the meditator struggles with the control of wandering mind. When the practitioner becomes skillful, positive emotions associated with subjective experience of joy, pleasure, and well-being emerge, which can further help sustain attention and the meditative state, thereby supporting mental processes and cognitive functioning (Tang et al. 2015).

Since one form of mindfulness meditation–IBMT involves systematic training of attention and self-control with an attitude of acceptance and openness to internal and external experiences, and has been tested in a series of randomized controlled studies, IBMT can be used as an example to demonstrate how brief training (a few hours) improves attention control (executive functions) and emotion regulation, reduces stress (cortisol), and increases ACC/mPFC activity related to better self-control abilities in healthy and patient populations. The control group was given the same amount of relaxation training that is often used as a part of CBT. Furthermore, relaxation training only includes body relaxation and mental imagery (but not mindfulness), which is an appropriate control condition of mindfulness meditation (Tang et al. 2007, 2009). Because IBMT shares key components with other forms of mindfulness meditation, we expect other mindfulness methods would show the similar effects.

In one study (Tang et al. 2007), college students were randomly assigned to an IBMT or a relaxation training group for five sessions of short-term training (20–30 min per session). The IBMT group showed significantly greater improvement of performance in executive attention control than the relaxation group, as measured by the Attention Network Test. Individuals in the IBMT condition also had lower negative affect and fatigue, and higher positive feelings on the self-report Profile of Mood States (POMS). In addition, IBMT can also decrease levels of the stress hormone cortisol and increase immune reactivity, suggesting health benefits (Tang et al. 2007). In another study, using the measurement of Positive Affect and Negative Affect Schedule (PANAS) with the same randomized design as mentioned earlier, brief IBMT showed significantly better positive mood states and lower negative mood states compared to relaxation training (Ding et al. 2014a, b). A similar study by another research team showed that in comparison with a waitlist control group, an 8-week mindfulness training program significantly reduced negative moods. These results indicated that mindfulness meditation can effectively improve self-control abilities, including attention control, emotion regulation, and stress response (Tang 2017).

How does mindfulness enhance emotion regulation? Evidence suggests that the present-moment awareness and nonjudgmental acceptance cultivated by mindfulness are crucial in promoting self-control, because they increase sensitivity to affective cues in the experiential field and improve response to incipient affective cues that help signal the need for control such as effective emotion regulation (Teper et al. 2013). In one of our studies, five sessions of IBMT increased brain theta activity in ACC and adjacent mPFC and emotion regulation (Tang et al. 2007, 2009). It should be noted that emotion regulation is not always deliberate, but can also operate in nonconscious or implicit levels (Koole et al. 2015). These implicit processes may allow people to decide whether or not to engage in emotion regulation, guide people in selecting suitable emotion regulation strategies, and facilitate the enactment of emotion regulation strategies (Childress et al. 2008). Over the last decade, studies have found some forms of psychopathology arise from deficits in implicit emotion regulation. For example, anxiety patients show significant deficits in the noninstructed and spontaneous regulation of emotion processing, suggesting abnormalities in emotion regulation could occur outside of awareness (Etkin et al. 2010). These results open avenues for novel and unconscious treatments, such as by targeting the mPFC/ACC (Tang et al. 2016a, b). These are in line with our recent IBMT results in which smokers improved emotion and changed their addiction behavior unconsciously through implicit processes (see Chap. 5).

To reveal the brain mechanisms of IBMT, college students were randomly assigned to IBMT or relaxation groups and underwent brain-imaging assessments before, during, and after five sessions of training. Neuroimaging data demonstrated that IBMT group showed stronger subgenual and adjacent ventral ACC activity compared to relaxation control. Based on previous research, this brain area is involved in emotion regulation and attention control. Since this area is also linked to autonomic nervous system (ANS), we thus measured the indexes of ANS activity such as heart rate variability, and found better parasympathetic regulation following brief IBMT (see Chap. 3 for details) (Tang et al. 2009). These results are consistent with IBMT's techniques in which IBMT stresses no effort or less effort to control thoughts explicitly, but instead emphasizes the achievement of a state of restful alertness naturally that allows a high degree of awareness and balance of the body, mind, and environment. Moreover, the meditation state is facilitated through body-mind training and trainer-group dynamics, harmony, and resonance led by a qualified IBMT coach or trainer (Tang et al. 2012a, b, c).

It should be noted that in addition to ACC/mPFC, which commonly is involved in attention and emotion regulation following brief IBMT, other brain areas such as dorsal lateral PFC and amygdala also participate in the top-down and bottom-up control networks. Some studies have detected these brain regions in different forms of mindfulness meditation, but we do not know exactly whether this observed phenomenon is due to different techniques or other factors such as effort or regulation strategies (Tang et al. 2015).

If five sessions of short-term IBMT improves attention and emotion regulation supported by the ACC activity, what will happen following longer IBMT practice? We expected that longer IBMT practice could induce structural change related to ACC and brain changes correlate with emotion regulation. Previous results using MRI diffusion tensor imaging have shown that training results in changes in white matter efficiency as measured by fractional anisotropy (FA), an index of integrity and connectivity of white matter. We randomly assigned undergraduates to an IBMT or relaxation group and acquired brain images from each participant at rest using diffusion tensor imaging for analysis of white matter changes before and after training. Results showed that around 10 h of IBMT (20 sessions within 4 weeks) increased FA in the corona radiata (Tang et al. 2010), an important white matter tract connecting the ACC to other structures, consistent with our hypothesis (see Fig. 2.1).

To measure the time-course of white matter change from 5 h (10 sessions within two weeks) to 10 h of training, we found, in comparison to relaxation training, 5 h of IBMT was only associated with axonal changes,

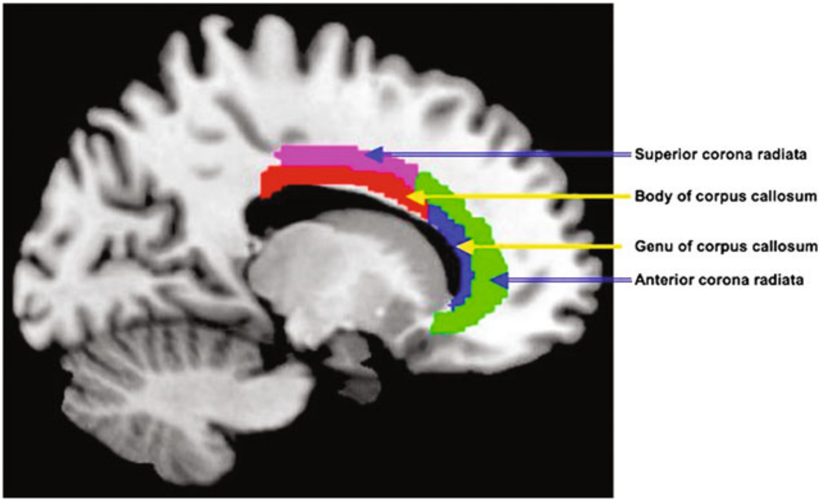

Fig. 2.1 Significant white matter changes following IBMT

but 10 h of IBMT increased both myelin and axonal changes, indicating improved efficiency of white matter involves increased myelin as well as other axonal changes. Moreover, in the study of 5 h of IBMT, there was a significant correlation between emotion regulation and axonal changes, indicating the training-induced change in emotion was correlated with the ACC structural changes (Tang et al. 2012a, b, c). If the aforementioned behavior change is supported by brain structural changes, does behavior change last longer? Our series of studies show that longer IBMT practice can lead to greater benefits, including better attention control in executive attention and sustained attention, emotion regulation, lower basal stress as measured by cortisol levels, and better immune function as measured by lower level of basal sIgA (Fan et al. 2010, 2013), suggesting a dose-dependent fashion following IBMT. Furthermore, IBMT also helps change addiction behaviors and habits see Chaps. 5 and 7).

The key region of self-control, the ACC, has been associated with many disorders, such as mood disorders, substance abuse, PTSD, and schizophrenia. The ability to strengthen ACC activity and connectivity through mindfulness training could provide a means for improving self-control and perhaps reducing or preventing various mental disorders.

In Chap. 7, I will provide several examples that will demonstrate the potential applications in the health field.

Brain Regions Related to Self-Awareness During Mindfulness

The self lies at the core of our mental life. Recent studies suggest that self-related processing often involves midline cortical structure, including DMN, which shows a high degree of spontaneous activity at rest (Northoff and Bermpohl 2004; Northoff and Panksepp 2008). Moreover, self-related activity, mindfulness meditation, and spontaneous DMN activity overlap partially in midline brain regions. As described earlier, during mindfulness meditation, we are continuously aware of whatever thoughts, sensations, and emotions entering our consciousness or/and monitoring the nature of awareness itself in an equanimous way to cultivate the meta-awareness of self (Tang et al. 2015). However, we encounter a paradox: on one hand we detach ourselves from our own self and its perception, cognition, and emotion during meditation; on the other hand, it is the self that meditates. In a nutshell, the paradox is that we detach from our self while, at the same time, relying on it to meditate. *How can we resolve that paradox?*

We suggest that different aspects of selves correspond to different stages of meditation (see Fig. 2.3). Cognitive self refers to the self involving our beliefs, thoughts, and concepts, which are often related to the wandering mind; the bodily-emotional self links to visceral, intuitive, and introceptive processing of self while wandering mind reduces. These two forms of self are associated with narrative and evaluative self-processing. The third form of self—the phenomenal-experiential self—refers to the self in one's present awareness. Meditation aims to detach oneself from the cognitive self (first stage) and bodily-emotional self (second stage); if one focuses too much on these selves, it can lead to distress and negative emotions. Detachment from both cognitive and bodily-emotional selves allows one to reveal and lay bare the most basic and fundamental self: the phenomenal-experiential (third stage). This allows one to return to one's own experience, including its temporal dynamics and attunement to the environment. Hence, meditation elevates the phenomenal-experiential self by making the detachment from the cognitive and bodily-emotional selves possible. Once one can distinguish the different forms of self, it becomes clear that detachment and elevation of self are no longer paradoxical, but rather become complementary and central aspects of meditation in its different stages.

A latest review of imaging studies in mindfulness meditation indicated that self-awareness involves ACC, DMN, and insula. Mindfulness practice alters the self-processing mode so that a previous narrative and evaluative form of self-processing is replaced by greater awareness (meta-awareness). This shift in self-awareness is one of the major active mechanisms of the beneficial effects induced by mindfulness meditation (Tang et al. 2015). Meditation seems to reduce activity in cortical midline structures including DMN, with more reduction in the posterior part, the PCC/precuneus, than in the anterior part, the mPFC, but increases perigenual ACC activity. Studies also indicate changes in the DMN and in control networks are associated with self-processing and top-down executive control, respectively, following mindfulness meditation. Different stages of meditation (early, middle, and advanced) appear to modulate the dynamic balance between anterior and posterior midline networks involved in different aspects of self: cognitive self, bodily-emotional self, and phenomenal-experiential self. These changes in cortical midline structures may reflect the self-plasticity following meditation practice. Given that meditation improves self-control ability, it has potential in the treatment of psychiatric disorders with self-disturbances.

As shown in Fig. 2.2, brain regions involved in the systematic training of attention and self-regulation during mindfulness meditation enhance attention control, improve emotion regulation, and alter self-awareness. Here we mainly focus on the brain regions of the ACC, PFC, striatum, insula, and DMN, which contribute to the behavior changes following mindfulness meditation.

Different Stages and Brain Networks

Mindfulness meditation can be roughly divided into three different stages of practice—early, middle (intermediate), and advanced—that involve different amounts of effort (see Fig. 2.3).

In the early stage of meditation, one uses lots of effort to control and combat the wandering mind (and its thoughts), and tries to get into the meditative state (termed as *effortful doing*). During this stage, the dorsal lateral PFC and parietal cortex are often involved. The middle stage of meditation still requires effort into the meditative state, but one learns how to recruit both mind and body into the desired state with less effort.

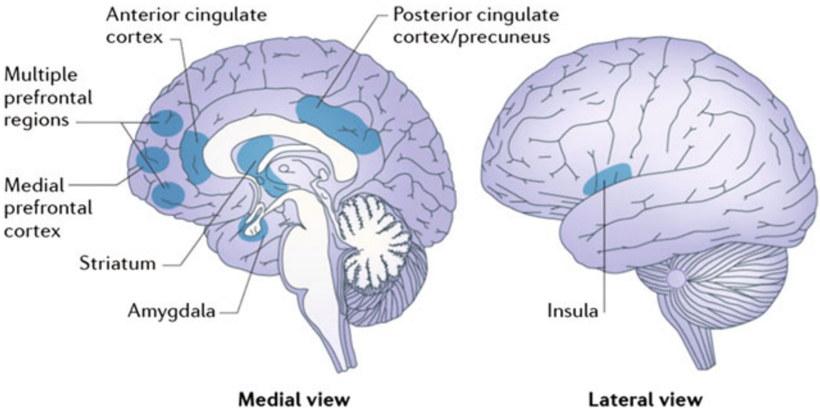

Fig. 2.2 Brain regions involved in mindfulness meditation. Schematic view of the brain regions consistently involved in attention control (ACC, PFC, and striatum), emotion regulation (multiple prefrontal regions, limbic regions, and striatum), and self-awareness (ACC, insula, mPFC, and PCC/precuneus)

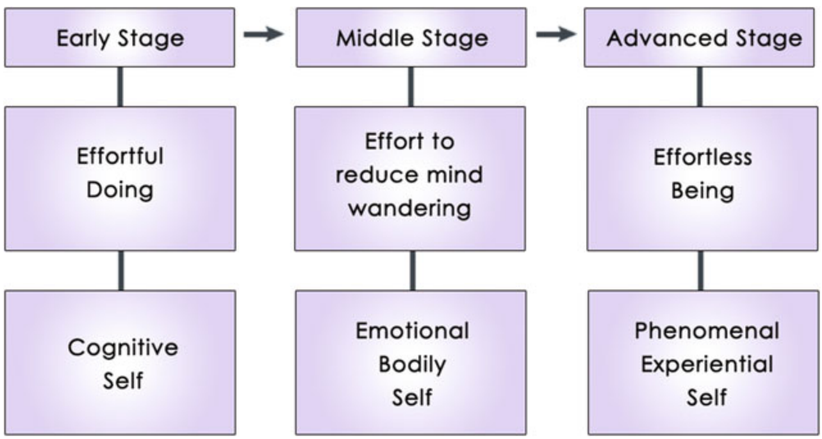

Fig. 2.3 Self, effort, and three stages of meditation

Therefore, ACC, different parts of PFC and striatum are mainly engaged. Although the mind and its various thought contents still wander, it does not bother the meditator any more; thus the meditator experiences more positive mood, relaxation, and calmness. The advanced stage of meditation often involves the flow of meditative state with less effort or even effortlessness, in which self and environment merge or dissolve and become one inherent experience (termed as *effortless being*). The brain networks of ACC and striatum are mainly involved at this stage (Tang et al. 2015; Tang and Posner 2009, 2014; Tang 2017). It should be noted that this chapter does not discuss the state beyond the advanced stage of meditation as described in Buddhism and other contemplative traditions.

In the same vein, different mindfulness meditation methods may involve different brain networks. For example, focused attention meditation mainly involves effort-based concentration on breath or sensation, and at the same time inhibits nontarget stimuli or distraction. This mental process mainly requires the lateral PFC and parietal cortex. However, with long-term practice, skillful meditators can exert less effort (effortless) to maintain the concentration meditative state. Studies have shown the reduced brain activity in lateral PFC associated with this advanced state. In contrast, open-monitoring meditation requires continuous observation and monitoring with less effort and gradually catches the arising of mental events. This process often involves the ACC and striatum networks and induces their functional and structural changes following short- and long-term practice (Tang et al. 2015).

State Training and Network Training

Mental training often refers to the practices that alter the brain/mind in a way that improves cognition, as well as performance in domains beyond those involved in the training. There are many forms of mental training similar to mindfulness meditation: computerized cognitive programs such as attention training, working memory training (WMT), and video games. To clarify the unique brain mechanisms following mindfulness meditation, we compare two brain-training strategies for improving performance: *state training* and *network training* (Tang and Posner 2009, 2014). Network training, such as a computerized cognitive program, involves practice of a specific cognitive task (e.g., attention, working memory) and thus exercises its specific brain network. *State training*, such as mindfulness meditation, uses practice to develop a brain state that may influence the operations of many networks. State training involves networks, but it is not designed to train networks using a specific cognitive task (Tang and Posner 2009, 2014; Tang et al. 2012a, b, c). Given the widespread interest and dramatic increases in many publications in WMT and mindfulness training, I will use WMT as an example of network training and mindfulness as an example of state training to reveal different brain mechanisms involved in these two training regimens.

Working memory involves the ability to maintain and manipulate information in one's mind while ignoring irrelevant distractions and intruding thoughts. WMT refers to training that exercises temporary storage of a small number of items either recently presented or retrieved from memory. Adaptive WMT requires maintenance of mental effort over the course of training. In general, studies after several weeks of WMT have shown that lateral frontal and parietal cortex are involved. However, we do not know whether increased brain activity is derived from greater overall task difficulty, more attention or effort needed to perform the task, or other factors (Tang and Posner 2014). As mentioned earlier, in the early stages of mindfulness, achieving the meditation state appears to involve the use of more attention control and mental effort; thus, areas of the lateral prefrontal and parietal cortex after training could be more active than before training. This may reflect the higher level of effort often found when participants struggle to obtain the meditation state in the early stage and thus provide greater overlap with what happens during adaptive WMT. However, in the advanced stages of mindfulness, prefrontal–parietal activity is often reduced or eliminated, but ACC and striatum (and insula) activity remains (Tang and Posner 2014; Tang and Tang 2015b). Moreover, mindfulness changes the frontal midline, including the ACC and its connections to the striatum and parasympathetic activity through ANS associated with self-control. These ANS and central nervous system (CNS) changes appear to differ from those in WMT, but insufficient effort has been devoted to a direct comparison of the two training methods.

In summary, among behavioral and brain imaging studies (e.g., functional and structural MRI), especially those based on longitudinal, randomized, and controlled designs with active control groups, mindfulness meditation as a state training regimen improves self-control abilities, including attention control (executive functions), emotion regulation, and self-awareness in healthy and patient populations. The ACC, PFC, striatum, insula, and DMN seem to show consistent changes associated with mindfulness meditation (Tang et al. 2015). Of course, mindfulness not only involves the CNS (brain) but also the ANS (body). In the next chapter, we will explore the physiology mechanisms of mindfulness meditation.

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CHAPTER 3

Physiology Mechanisms of Mindfulness Meditation

Abstract In addition to brain changes, mindfulness meditation is also accompanied by ANS changes such as breath amplitude, heart rate, and skin conductance. Descriptions of mindfulness often emphasize mind or thought processes and the role of the body has often been ignored. In fact, body and mind can never be separated in mindfulness practice and daily life. Therefore this chapter focuses on the physiology mechanisms of mindfulness meditation and discusses the interaction between the CNS (brain) and the ANS (body) that both support the meditation practice and outcomes.

Keywords Heart rate · Skin conductance · Autonomic nervous system (ANS) · Physiology

Body Supports Mind Process

In psychological research, embodied cognition studies how physical experience influences understanding and cognitive function. One recent study explored the importance of physical experience in science learning in a college physics class. The hypothesis is that students' understanding of science concepts such as torque and angular momentum is aided by sensorimotor activation in the brain that could add kinetic detail and meaning to students' thinking. Results showed that the physical experience—a brief exposure to forces associated with angular momentum—significantly improved quiz scores. Moreover, improved performance was explained by sensorimotor activation when students later reasoned about angular

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momentum (Kontra et al. 2015). These findings are consistent with the mechanism of embodied cognition.

Research has also shown that embodiment (body posture and state) not only affects mental processes such as thinking and feeling, but also influences physiology and subsequent behavioral choices. For example, humans and animals express power through open and expansive postures, whereas express powerlessness through closed and contractive postures, so one study examined whether a brief power posing (nonverbal displays) affects neuroendocrine levels and risk tolerance. Results showed that high-power posing induced increases in the sex hormone testosterone, decreases in stress hormone cortisol, and increased feelings of power and tolerance for risk; but low-power posing exhibited the opposite pattern (Carney et al. 2010). These findings suggest that embodiment extends beyond mere thinking and feeling, to physiology (neuroendocrine) and subsequent behavioral changes. This study also provides insight into the utilization of powerful posing to produce advantaged and adaptive psychological, physiological, and behavioral changes in the real world. However, it should be noted that this strategy of powerful posing should be consistent with social norm. For example, to express power a job candidate shows expansive body postures to the job interviewer, but this behavior is often taken as an inappropriate one and may lead to failure.

Mindfulness Starts with the Body

In mindfulness practice, almost all the methods emphasize the body's role. As shown in a review article on mindfulness of the body, one of the core techniques of mindfulness meditation is paying attention to body sensation and feeling (body-focused attention); for example, using a meditative body scan practice of "moving a focused spotlight of attention from one part of the body to another" (Kerr et al. 2013; Tang and Tang 2015). This mindfulness practice with somatic focus is still processed in the mind, but it could amplify and strengthen the connections among bodily sensory input, feeling, and mental process.

Interoception is the sensing of physiological signals originating inside the body, such as heart rate, hunger, and pain. Using an interoceptive awareness task wherein subjects judged the timing of their own heartbeats, fMRI results indicated enhanced activity in insula, somatomotor, and cingulate cortices (Critchley et al. 2004). Moreover, neural activity in right anterior insular/opercular cortex predicted subjects' accuracy in the heartbeat detection task. It has often been reported that the mindfulness practice of attending to present-moment body sensations results in an enhanced awareness of bodily states and greater perceptual clarity of subtle interoception. Although studies did not find evidence that meditators had superior performance than nonmeditators using a heartbeat detection task—a standard measure of interoceptive awareness—other studies found that meditators showed greater coherence between objective physiological data and their subjective emotional experience and the sensitivity of body regions (Tang et al. 2015). It should be noted that heartbeat detection task often induces more sympathetic activity, which involves the right insula. However, after five sessions of training, the IBMT group showed more left insula activity when compared with the relaxation group, consistent with the previous findings that the left insula is predominantly responsible for parasympathetic effects. These data suggest that brief mindfulness practice such as IBMT can increase parasympathetic activity that serves to support the meditative states (Tang et al. 2009).

Based on previous research, I have proposed that mindfulness states can be achieved in two ways: through mental processes (e.g., mindfulness) and through bodily processes (e.g., bodifulness). The bodifulness refers to the gentle and holistic adjustment and exercise of body posture through balanced and harmony techniques. For instance, in Eastern traditions, practices like IBMT, TCM-based methods (e.g., Tai Chi, Qigong), and yoga, apply body-mind balance and interaction techniques to facilitate the body-mind states and positive outcomes (Tang and Tang 2015; Tang 2017).

Mindfulness involves an explicit process (e.g., counting your breath) through the CNS (brain/mind), but bodifulness mainly involves implicit process (e.g., visceral or interoceptive awareness) regulated by the ANS. Autonomic control needs less effort supported by the ACC and adjacent mPFC. However, at the early stage, mindfulness requires conscious cognitive control with effort and is supported by the lateral PFC and parietal cortex, but requires less effort as the practice becomes more skilled in the advanced stage. When the mental process of mindfulness through cognitive control becomes automatic and can be internalized into the body (via autonomic control), a state of bodifulness is formed. Cognitive control and autonomic control are both important components of self-control, which facilitates meditative states and drives behavior and habit formation (Tang and Tang 2015; Tang 2017). Figure 3.1 illustrates an integrative model for changing brain states through body-mind training.

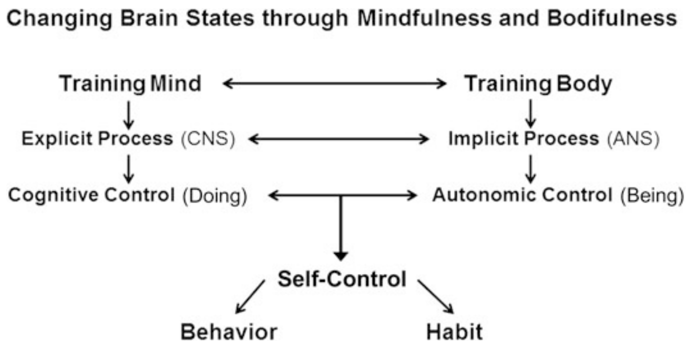

Fig. 3.1 An integrative model for changing brain states through mindfulness and bodifulness

Mechanisms of Body-Mind Interaction

A series of studies have indicated that meditation regulates ANS function and induces physiological changes such as oxygen consumption, heart rate, respiratory amplitude and rate, skin conductance, heart rate variability (HRV), and other indices, suggesting the dominance of parasympathetic activity following meditation practice. Moreover, the awareness of body's functioning and practice of bodifulness techniques also facilitates the mindfulness process. This is in line with the embodiment literature that body posture and state change mental processes. In other words, our body postures change our chemistry, our bodies change our minds, and our minds change our behavior (Tang et al. 2015; Tang and Tang, 2015; Tang 2017).

Does mindfulness meditation change neurophysiology? A recent systematic review of electroencephalogram (EEG) studies of mindfulness meditation (with a total of 1715 subjects) examined EEG power outcomes in each bandwidth, in particular the power differentials between mindfulness and the control state, as well as outcomes relating to hemispheric asymmetry and event-related potentials. The results suggested that mindfulness was most commonly associated with enhanced alpha and theta power as compared to an eyes-closed resting state. No consistent patterns were observed in beta, delta, and gamma bandwidths. This co-presence of elevated alpha and theta may signify a state of relaxed alertness, which leads to health and well-being (Lomas et al. 2015).

To further study the mechanisms of body-mind interaction, in two randomized studies, we applied brain imaging and physiology measures in five sessions of IBMT and relaxation training groups. We first found stronger subgenual/ventral ACC activity in the IBMT group. Since this area is also linked to the ANS, we then measured the HRV and skin conductance response (SCR), the indices of sympathetic and parasympathetic activity. During and after training, the IBMT group showed significantly better physiological reactions in heart rate, and respiratory amplitude and rate when compared with the relaxation control. We also found that compared to relaxation training, IBMT significantly improved high-frequency HRV and reduced SCR, suggesting better parasympathetic regulation. Meanwhile, EEG power showed greater ACC theta brain activity. Frontal midline ACC theta was correlated with high-frequency HRV, suggesting control by the ACC over parasympathetic activity. These results indicate that after five sessions of training, the IBMT group shows better regulation of the ANS by a ventral midline brain system than does the relaxation group. This changed state probably reflects training in the coordination of body and mind given in the meditation group, but not in the control group. Therefore, both ACC and ANS may serve as mediating brain mechanisms that link IBMT with improvements in attention control and emotion regulation as well as other behaviors (Tang et al. 2009).

From a practice perspective, meditation relying solely on mind control (without body engagement) could often lead to a "dry" practice experience; that is, practitioners exert considerable effort into mind control and usually find it difficult to achieve meditative states. As a result, this process is usually associated with mental fatigue, negative emotion, and difficulty in learning to meditate. This is consistent with previous findings that brain and mind work together to support efficient meditation states.

How to cope with stress effectively? Generally speaking, stress has two types: (1) somatic stress in the body, e.g., a racing heart, indigestion, or the jitters; and (2) stress in mental cognitive stress, e.g., worrisome thoughts that keep one up at night or that continually intrude into one's attention during the day. Most importantly, the stress from body and mind work together and interact. Research indicate that there is no single best way to erase cognitive or/and somatic anxiety, including meditation and yoga. Not everyone will benefit from a body-focused method, just as meditation may not be the best way to fight stress for each person. However, *a body-mind technique that can help you relax your body and calm your mind seems a promising choice and is worth the effort*. It has been shown, for example, that IBMT can reduce stress measured by salivary hormone cortisol (body domain) and self-reported scales (mind dimension). When we calm down from stress, we are shifting our nervous system to the relaxation and calm state known as parasympathetic dominance. In this state, our minds are more open and clear, our heart rate slows, breath deepens, and our muscles relax, which can release the rooted stress and tension (Tang 2017).

In sum, mindfulness meditation involves the interaction and harmony between the CNS (brain) and the ANS (body) that support effective practice and positive outcomes.

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CHAPTER 4

Traits and States in Mindfulness Meditation

Abstract Personality is the collection of characteristic thoughts, attitudes, feelings, and behaviors that impact how we view ourselves and what we believe about others and the world around us. In general, personality traits are relatively stable characteristics, but states are transient. Research has shown that our beliefs and attitudes are learned and shaped by our own experience and expectation, and that these are not fixed and can be changed. Studies have shown that mindfulness induces state changes that influence cognition, feelings, and corresponding brain activity and connectivity after short-term training, and traits changes are also found following long-term practice. This chapter explores how traits and states contribute to mindfulness practice, and explain how this knowledge could improve our practice efficiency.

Keywords Personality · Temperament · Trait · State

Individual Differences

It is known that people differ in their attitude towards the practice of mindfulness meditation, and that not everyone shows the same level of change after mindfulness training. However, we know little about how training might differ among individuals. For example, studies show that mindfulness meditation changes brain structure in the ACC and insula associated with self-control and awareness. If some people are born with a greater ACC or insula than average, might these people be naturally more able to focus

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attention or more inclined to meditation? It is likely that such differences will make it impossible to determine which method would be most efficient for each individual. In our review article *The neuroscience of mindfulness meditation*, we focused on the neural mechanisms and consequences of mindfulness meditation. However, it is also important to differentiate between dispositional mindfulness (also known as trait mindfulness) and deliberate (intentional) mindfulness. Both may reflect the possible individual differences in mindfulness practice. Although our review mainly investigated mindfulness as an intentional practice, pre-existing differences in trait mindfulness could have affected the findings described (Tang et al. 2016a, b).

So far, relatively little is known about how differences in dispositional mindfulness might influence brain processing and the effective practice of mindfulness. However, a number of studies have investigated the neural correlates of dispositional mindfulness and have identified some functional and structural brain areas that are involved. Unfortunately, these reports are not consistent. Several factors could contribute to this inconsistency, but one of the reasons may be related to the assessment methods of trait mindfulness.

Measuring Trait or Dispositional Mindfulness

Trait mindfulness is usually assessed through self-report questionnaires, such as the Mindful Attention Awareness Scale, the Kentucky Inventory of Mindfulness Skills, and the Five Facet Mindfulness Questionnaire. However, the use of these questionnaires comes with specific challenges and limitations, which have been extensively discussed by others. For instance, a recent review concluded that the evidence to support the validity of these questionnaires is lacking (Park et al. 2013; Grossman 2011). It is therefore important to remember that what is being interpreted as "dispositional or trait mindfulness" is actually what these questionnaires assess. All of these challenges call for a more objective measurement of trait mindfulness; for instance, physiological or/and brain biomarkers (Tang et al. 2015).

State and Trait Changes Following Mindfulness

Growing evidence has indicated that mindfulness practice induces both state and trait changes. For example, mindfulness meditation can not only temporarily change the condition of brain and its corresponding pattern of activity or connectivity (state change), but also alter personality traits following a longer period of practice. Researchers had traditionally assumed that personality traits are relatively stable entities, but more recent research demonstrates that personality, including disposition towards mindfulness, can change over time as a result of life experiences or through mindfulness practice (Crescentini and Capurso 2015), suggesting that personality itself is flexible. Although this demonstrates that individuals can change the way they feel, believe, and act, the finding also complicates the systematic investigation of the construct of 'trait mindfulness'. Nevertheless, recent evidence suggests that it is important to assess trait mindfulness at different points during studies that aim to investigate and distinguish the effects of mindfulness meditation from intentional mindfulness. Individual differences in personality are likely to contribute to how people respond to and benefit from mindfulness practice, in the same way that differences in brain function and structure, genetic predisposition, life experiences, and environmental factors do (see Fig. 4.1). However, little is known about what temperamental, personality, or genetic differences contribute to these differential training effects (Tang et al. 2015, 2016a).

As in other fields, it may be that the study of temperament and personality differences by questionnaires serves as an important level of analysis to predict success in mindfulness training. Using the control condition as baseline, one study showed that in Zen meditators, the percent change in slow alpha EEG power in the frontal area, reflecting enhanced internalized attention, was negatively correlated with low-frequency HRV (as sympathetic indices) and was positively correlated with the novelty seeking score

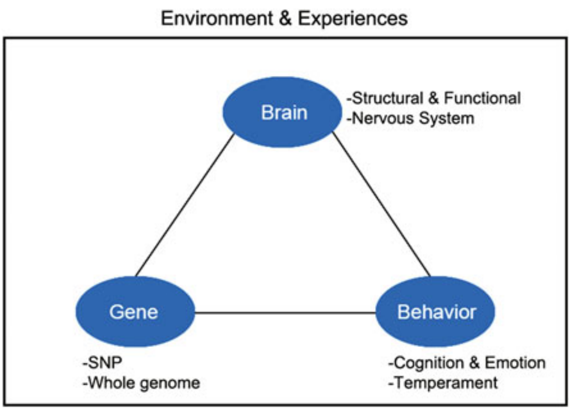

Fig. 4.1 Gene-brain-behavior-environment interaction in mindfulness meditation

in Cloninger's Temperament and Character Inventory (TCI); whereas the percent change in fast theta power in the frontal area, reflecting enhanced mindfulness, was positively correlated with high-frequency HRV (as a parasympathetic index) and also with the harm avoidance score in TCI. These results suggest that internalized attention and mindfulness (two major core factors of behaviors of mind during meditation) are characterized by different combinations of EEG patterns and HRV and personality traits (Takahashi et al. 2005).

Could we predict performance or behavior following mindfulness? Our studies have shown a mean improvement in creative performance following IBMT; however, differences among individuals have been neglected. We thus examine whether short-term IBMT can improve creative performance and seek to determine which type of people are most likely to benefit. In a randomized study using short-term IBMT and the same amount of relaxation training (30 min/session/day for a week), mood (Profile of Mood States), personality (Eysenck Personality Questionnaire), and creative performances (Torrance Test of Creative Thinking) were assessed before and after training. Results indicated that the IBMT group had significantly greater creative performance than the relaxation group, consistent with previous results. A linear regression showed that five predictors in pre-tests including depression, anger, fatigue, introversion × vigor, and emotional stability × vigor accounted for 57% of the variance in the change in creativity before versus after IBMT. In this way, we demonstrated substantial differences among individuals whose training effects were correlated with aspects of their mood and personality. Our results also suggest that mood and personality could be useful tools to predict individual variation in the improvement of creative performance following mindfulness training (Ding et al. 2014a, b).

Do genes and environment (or experience) interact to influence the success of mindfulness training? Studies of training effects in other domains have suggested that a number of genetic polymorphisms may interact with experience to influence the success of training. For example, DRD4 gene (one of dopamine receptor genes) is involved in executive attention and self-control. The 7-repeat allele of the DRD4 gene has been associated with attention-deficit/hyperactivity disorder (ADHD) and the temperamental quality of sensation seeking. Evidence that environment and/or experience can have a stronger influence in individuals with the 7-repeat allele has been reported. Moreover, in a randomized study, an intervention that increases parents' use of positive discipline reduced externalizing behavior in toddlers with the 7-repeat allele of the DRD4 gene, significantly more so than those without this allele.

How do these differences arise? On one hand, they are due to genetic variations. On the other hand, environmental influences and learning can also lead to differences. Therefore, experience and genetics are not separate influences but they frequently interact. Gene expression, for example, can be altered by the environment in which the genes operate. Genetic differences can also influence the degree to which specific experience is effective in leading to learning. Our genes thus influence the degree to which our behavior is altered by experience. These results illustrate the complex interaction between genetic variation and environmental influence such as experience (Belsky et al. 2009; van Ijzendoorn et al. 2011).

Given that there is evidence of mindfulness meditation influencing behavior and activation and connectivity of the ACC, PFC, striatum, and other brain regions, it may be useful for future research to examine polymorphisms in dopamine genes and their likely influence on the success of meditation practice. In addition, individual differences in personality and lifestyle, and trainers and group dynamics during training, are likely to have significant influence on training effects, but this influence is poorly understood. However, more empirical studies are needed to establish a definitive effect of these factors on mindfulness. We believe that more longitudinal, randomized, and actively controlled studies with larger sample sizes could deepen our understanding of how we could help people with different personality traits practice effectively (Tang et al. 2015, 2016a).

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CHAPTER 5

Mindfulness Meditation and Behavior Change

Abstract Although mindfulness meditation has shown beneficial effects on cognition, emotion, health, and brain plasticity, the relationship between brain mechanisms of mindfulness meditation and behavior change is not yet well-established. Does mindfulness help with behavior change, such as smoking cessation or weight loss? Building on the latest research, this chapter proposes a brain-based model and mechanism underlying behavior change through mindfulness meditation, which includes attention control (persistent focus on target or goal), emotion regulation (positive emotion, reinforcement, and reward), and self-awareness (interoceptive observation and monitoring with equanimity). We use smoking cessation and weight loss as examples of behavior change because these are persistent problems in our society, but are difficult behaviors to stop. We also discuss how "focused attention" and "open-monitoring" mindfulness meditation can support behavior change.

Keywords Focused attention · Open monitoring · Behavior change · Unconscious

Mindfulness Components and Behavior Change

Behavior change usually involves several important factors including motivation, goal setting, action, and behavior maintenance (Prochaska et al. 1994; Wiers et al. 2007; Wood and Rünger 2015). There are many methods that have been developed to target one or several aspects of

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behavior change. Specifically, behavior change could happen in both automatic (implicit) and controlled (explicit) ways (Ansorge et al. 2014; Baumeister and Bargh 2014). Generally speaking, these processes require at least attention control, emotion regulation, reward and reinforcement, self-awareness, and monitoring of behavior, all of which mindfulness meditation can strengthen and improve.

As we discussed earlier, attention control supports persistent focus on a target or goal, one of the key factor of behavior change. Emotion regulation helps increase positive moods, reinforcement, and feelings of joy and thus facilitates consolidation of beneficial habits and routines. Self-awareness involves interoceptive observation and monitoring with equanimity that can provide awareness of momentary behavior or behavior change, thereby facilitating behavior change consciously and/or unconsciously. In sum, mindfulness practice supports and facilitates behavior change through training attention, emotion, and self-awareness (Hölzel et al. 2011; Tang et al. 2015).

Conscious and Unconscious Processes in Mindfulness

In general, conscious regulation works through PFC-based attention control networks, whereas unconscious regulation works via striatum-based habitual networks (Tang and Posner 2009, 2014). For example, in the addiction literature, one hypothesis is that the seeking and taking of drugs can be understood in terms of interactions among Pavlovian and instrumental learning and memory mechanisms that automatically drive drug consumption (Everitt 2014). In other words, studies have shown that addiction can be viewed as a transition from voluntary, recreational drug use for seeking the reward (activation of the NAc in the striatum), to compulsive drug-seeking habits, neurally underpinned by a transition from PFC control to dorsal striatal automatic drug seeking and consumption that entails a progression from the ventral (location of NAc) to the dorsal striatum (Everitt and Robbins 2016). These results suggest that the abnormalities of brain's reward network play a key role in the automatic and unconscious addiction behavior. Neuroimaging studies on successful behavioral interventions in addiction including mindfulness meditation, have commonly shown the normalization of aberrant activity in the brain's reward circuitry (Zilverstand et al. 2016).

Mindfulness practice induces both conscious and unconscious changes (Tang and Tang 2015b). Importantly, except for the positive emotion, pleasant feeling, and reward experience, mindfulness practice also changes brain function and structure in the caudate and putamen, parts of the striatum. For instance, a form of mindfulness meditation IBMT increases brain activity in the ventral PFC/ACC following short-term practice, whereas long-term practice changes the activity of both the ventral and dorsal PFC, including the ACC, and the functional activity and structural changes in the striatum (caudate and putamen), suggesting a transition from conscious control to unconscious habitual action (Tang et al. 2009, 2010, 2012a, b, c, 2013a, b, 2014). This transition of brain changes may provide neural foundation for effective behavior change, both consciously and unconsciously through mindfulness practice. The caudate nucleus and putamen are known for their roles in reward-based learning, and activation of the NAc is associated with pleasant feelings facilitating learning consolidation and habit formation. Mindfulness meditation has been shown to induce subjective experience of joy and well-being, and to increase dopamine release and trigger functional and structural changes in the striatum, suggesting it could serve as a brain-based intervention for conscious and unconscious behavior change (Kjaer et al. 2002; Hölzel et al. 2011; Hagerty et al. 2013; Tang et al. 2009, 2014, 2015; Tang and Posner 2014).

Mindfulness practice is often associated with reduced intensity and frequency of negative affect, and improved positive mood states (Tang et al. 2015). One major mechanism is that mindful emotion regulation works by strengthen-ing prefrontal cognitive control and thus down-regulates brain activity in regions relevant to emotion processing, such as the amygdala. Awareness of present moment and nonjudgmental acceptance through mindfulness, are thought to be crucial in promoting cognitive control because they increase sensitivity to affective cues that help to signal the need for control (Teper et al. 2013; Tang et al. 2015). Research suggests that the level of expertise of mindfulness is important when it comes to emotion regulation, with beginners showing a different pattern from expert meditators: from enhanced top-down to bottom–up emotion regulation. This finding is in line with the hypothesis that the process of mindfulness meditation is characterized as active cognitive (attention) regulation in meditation beginners, who often need to overcome habitual ways of internally reacting to one's emotions and wandering mind, therefore often exhibiting greater PFC activation. In contrast, expert meditators have automated an accepting stance towards their experience and thus no longer require top-down control efforts, but instead show enhanced bottom–up processing, suggesting the trend from conscious and explicit processes to unconscious and implicit changes (Chiesa et al. 2013; Teper et al. 2013; Tang et al. 2015; Tang and Tang 2014, 2015).

Why Is It so Difficult to Change Behavior via Conscious Control?

A popular TV program, *The Biggest Loser*, is known for its incredible weight-loss makeovers. In this program, following guidance of fitness trainers and keeping intensive dieting and exercise, the contestants with strong motivation and willpower work hard and intensively to burn calories and lose weight within several months. Meanwhile, they have the opportunity to win money. Some contestants won the competition and lost hundreds of pounds during the TV program seasons, but unfortunately, they gained back weight afterwards based on a six years of follow-up study. Similar situations often happen for smokers with strong intention and will power to quit, but they often fail. These results suggest that behavior change is difficult even if one has strong motivation and conscious control. Then why do so many people struggle and fail to keep off the weight they lose or quit their smoking habit?

Studies have shown that consciousness is not needed to originate behavior. Conscious intent and awareness of the pursuit goal are not necessary to produce goal-directed behavior (Baumeister and Bargh 2014). Unconsciousness influences consciousness and vice versa. While this phenomena cannot be directly observed with the conscious mind, it can be modified indirectly through improved regulation of consciousness. Given the strong habitual power of unconsciousness that can drive behavior automatically, consciousness and conscious control often play weak roles in detecting and executing behavior change (Bargh and Chartrand 1999; Suhler and Churchland 2009; Baumeister and Bargh 2014). Another important factor is that in daily life the origination and initiation of behavior includes consciousness, perception or cognition, sensation or feeling, and reaction, which all move too fast for awareness to reach consciousness, thus it is hard to detect and control the behavior immediately with consciousness. Thus, in reality, external cues often activate automatic and unconscious processes that produce behavioral responses faster than our conscious mind can catch up.

How to Induce and Affect Behavior Change Unconsciously

Would it be possible to change behavior unconsciously through mindfulness meditation? To answer this question, we conducted a randomized smoking intervention study in smokers and nonsmokers who were interested in general stress reduction but not quitting smoking. Compared to relaxation training, five hours of IBMT produced significant smoking reduction, quitting, and decrease in craving. Meanwhile, brain imaging showed increased activity for the IBMT group in the ACC/PFC, brain areas related to self-control (Tang et al. 2013a, b). Importantly, participants were not aware of the smoking behavior change during and after intervention, suggesting the unconscious process through mindfulness meditation. The results indicate the possibility of unconscious behavior change. As we know, most addicted individuals fail to seek treatment and such "denial" may reflect dysfunction of brain networks subserving self-awareness (Goldstein et al. 2009). In contrast, mindfulness meditation improves self-awareness and helps practitioners to be aware of their own thinking and thought processes, which in turn facilitates openness and acceptance of thought, emotion, and experience in an equanimous way. This is one mechanism of how mindfulness works on self-awareness deficits in addictions, and changes addictive behavior (Tang et al. 2015, 2015c).

Does autonomic nervous system (ANS) support unconscious change? Studies have shown that modulation of the ANS, a critical component in the homeostatic regulation of the body, is predominantly and mainly related to unconscious processing. It is therefore reasonable to speculate that a method that strengthens the functioning of both body and mind may produce behavior change effectively. Mindfulness meditation trains and improves self-awareness and provides an opportunity to monitor and detect the fast unconscious change of sensation. Moreover, mindfulness practice could improve interaction between the ANS and the CNS (Tang et al. 2009, 2014). In a randomized study that compared IBMT vs. relaxation training, participants who underwent IBMT showed stronger ACC activity. Further, frontal midline ACC theta correlated with high-frequency HRV (index of parasympathetic activity) in the IBMT condition, suggesting control by the ACC over parasympathetic activity (Tang et al. 2009). Together, these results indicate that both the ACC and the ANS may serve as mediating brain mechanisms linking IBMT with improvements in self-awareness and self-regulation. Therefore, ACC may connect and trigger conscious and unconscious regulation through CNS-ANS interaction, and thus influence unconscious control of behavior change (Tang and Tang 2015b). These results are line with the previous findings of ACC's role in translating conscious cortical representations and computations into efferent autonomic and unconscious bodily response and control.

Every thought and sensation is at first unconscious and later rises to consciousness. We often become aware of such things only after they have arisen in the conscious realm and stayed there for some time. To deal with prompt habitual reaction, we have to extend our awareness down into this unconscious world and detect the arising thought and sensation as fast as possible. That is not easy, but we can learn through open-monitoring meditation—a mindfulness practice with less effort—and gradually catch mental events as they arise. In IBMT teaching and learning, we often use this technique. In contrast, focused attention meditation mainly involves effort-based concentration with inhibition of nontarget stimuli, it does not directly affect unconscious mind. However, with focused attention practice, concentration could slow down the rise of these mental events and give us time to feel each one arising out of the unconscious even before we see it in consciousness. In other words, concentration helps us see thoughts and sensations arising slowly from the unconscious mind. This gives us the power and time to produce immediate awareness and possibly break into the automatic and habitual cycle, to control and change behavior both consciously and unconsciously. We believe this process is an effective way of making the unconscious conscious (Tang 2009). Studies have suggested that ANS (body) and CNS (mind) coordination is supportive of behavior change based on our model below (Tang 2017).

Integrative Brain Model of Behavior Change Through Mindfulness

We propose an integrative brain model of behavior change through mindfulness (see Fig. 5.1). This model includes both unconscious/implicit and conscious/explicit regulation of behavior change.

It should be noted that to trigger behavior changes through conscious control, one need not overly push the goal or intention. For example, a recent study showed that incidental exposure to no-smoking signs (more reminders of no smoking) could ironically boost cigarette-approach tendencies in smokers (Earp et al. 2013). Studies also showed that behavioral control could be undermined by motivational processes *outside awareness.*

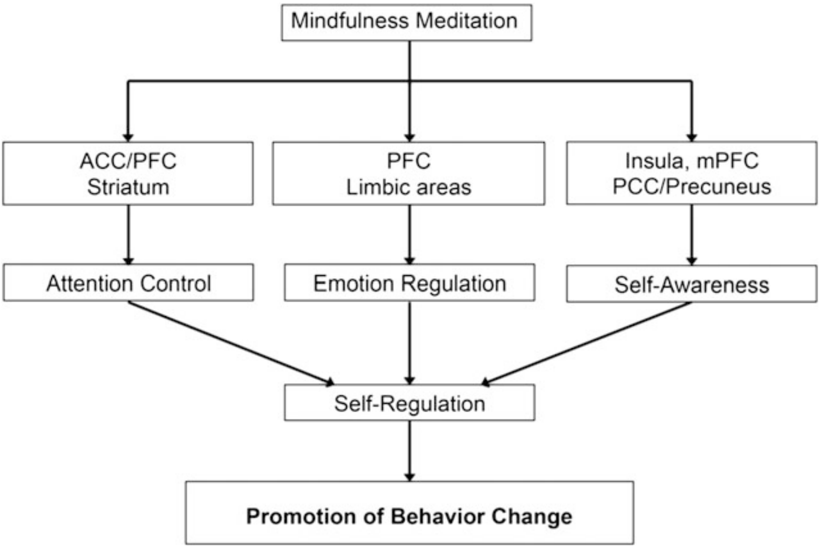

Fig. 5.1 A brain-based model underlying behavior change through mindfulness meditation

In an fMRI study, a 33 ms "unseen" visual of cocaine cues (below the threshold for conscious recognition, without explicit awareness of these cues) activated the limbic reward circuitry and the brain activation to unseen cues predicted future positive affect to the same visible cues. These results indicated the functional significance of the "unseen" cues, consistent with findings showing that appetitive signals outside of conscious attention can influence ongoing or subsequent motivated behavior (Childress et al. 2008; Pessiglione et al. 2007; McCabe et al. 2009). Our recent work on brain mechanisms of smoking reduction through brief mindfulness (IBMT) also suggested that behavior change does not correlate with conscious intention or motivation but instead involves more unconscious processing (see details in Chap. 7), consistent with our model of unconscious and conscious behavior change (Tang et al. 2015c). Altogether, these results raise a question about how to trigger behavior change effectively. In the next chapter, we will introduce mindfulness applications in education.

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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 non-reactive 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 sub-cortical 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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CHAPTER 7

Mindfulness Applications in Health and Mental Disorders

Abstract The ability to exercise self-control is a vital aspect of human adaptability, and fundamental to health and well-being. Problems associated with self-control deficiencies are common and are associated with diverse behavioral problems and mental disorders. This chapter focuses on the effects of mindfulness on health and mental disorders such as stress reduction, immune function, addictions, ADHD, depression and aging. We suggest that mindfulness is an interventional technique that is beneficial to health and well-being, as well as an attitude and skill that can become a healthy habit and even a lifestyle.

Keywords Addiction · ADHD · Aging · Stress reduction · Immune function · Depression

Stress Reduction and Immune Function

Stress plays a key role in health and mental disorders. Psychological stress leads to the secretion of stress hormone cortisol. While this psychoneuroendocrine response helps to maintain physiological as well as psychological homeostasis under stress, exaggerated release of cortisol can suppress aspects of immune function and have negative effects on health. One of our studies investigated the dynamic changes in salivary secretory immunoglobulin A (sIgA), an immune function index, and cortisol before and after acute stress, and to analyze the relationship between sIgA and cortisol (Fan et al. 2009). All healthy subjects underwent an acute stress

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test (mental arithmetic task). Salivary cortisol and sIgA responses were assessed repeatedly before the stress test, immediately after the stress test, and 20 min after the stress test. We found that the levels of salivary cortisol and sIgA both significantly increased after the acute mental arithmetic challenge, suggesting this stress task was very successful. However, the increase of sIgA was transient and did not last long; the sIgA fall was significantly correlated with the cortisol rise during the 20 min after stress. These results may help determine the timing of effective intervention in order to reduce the hypersecretion of cortisol and improve mucosal immune function (Fan et al. 2009). Therefore, in our and other studies, the 20-min period after stress has become an important time window for measurement of changes in stress hormone and immune function.

Does mindfulness practice show a dose-dependent fashion? Prior research has shown that an additional training session immediately after acute stress decreases release of salivary cortisol in a college student group trained with five sessions of IBMT in comparison with a control group given the same amount of RT. However, five sessions of training does not influence the basal secretion of cortisol (Tang et al. 2007). To determine whether increasing amount of IBMT could decrease the basal cortisol level, we conducted another study in healthy college students and randomly assigned them to either 4 weeks of IBMT or relaxation control (20 sessions of 30 min per session). We assessed salivary cortisol levels at baseline before training, as well as during the three stages of a stress intervention test including rest, stress, and additional 20-min practice after 2 and 4 weeks of training. The basal cortisol level decreased significantly in the IBMT group but not in the relaxation group after two and four weeks of training. An additional IBMT practice session immediately after acute stress produced significantly lower cortisol release in the IBMT group in comparison with the relaxation group at weeks two and four. These results indicate that IBMT produces changes in the basal endocrine system and larger acute effects as the dose of training increases, suggesting reduced stress in daily activities. We conclude that cortisol level is modulated by IBMT in a dose-dependent fashion (Fan et al. 2013).

If cortisol level shows this pattern following IBMT in a dose-dependent fashion, *how about immune function sIgA?* As we already know, an additional training session immediately after acute stress increased release of salivary sIgA in a group trained with five sessions of IBMT in comparison to a control group given the same amount of RT. However, this amount of training did not influence the basal secretion of sIgA. The current study aims to extend this finding and determine whether increasing amounts of IBMT increases the basal sIgA level, suggesting further improvements in mucosal immune function. Healthy undergraduates were randomly assigned either to an IBMT group receiving four weeks of IBMT or a relaxation control. Salivary sIgA levels at baseline before training and three stages (i.e., rest, stress, and additional 20-min practice) after two and four weeks training were assessed. We found that the basal sIgA levels increased significantly in the IBMT subjects but not in controls after 4 weeks of training. An additional IBMT practice session immediately after acute stress produced significantly higher sIgA release for the IBMT group in comparison with controls at week two and four. This effect was larger at week four than week two. These results indicate that IBMT produces changes in the basal immune system and larger acute effects as the dose of training increases. In sum, brief mindfulness IBMT can significantly reduce stress hormone cortisol while increasing immune function sIgA and has positive effects on health and well-being (Fan et al. 2010).

ADHD

In addition to the attention improvement in healthy populations discussed in previous chapters, here we will discuss the brain mechanism of ADHD and explore brain-based effective treatment. ADHD is a chronic neurodevelopmental disorder characterized by impulsivity, hyperactivity, and an inability to focus. Studies have shown that ADHD has impact on brain function and structure, and causes learning difficulties, school failure, and behavioral problems in children, adolescents, and college students (Plichta and Scheres 2014). However, whether brain abnormalities are the consequence of ADHD or serve as a precursor of ADHD remain unclear.

ADHD brain. The prefrontal cortex (PFC), striatum, thalamus, and motor system including the cerebellum often show dysfunction in ADHD (Bush 2011). These neurocircuitries play an essential role in flexible behavior, and the dysfunction of circuits increases the risk of behavioral issues and symptoms such as ADHD. Functional and structural neuroimaging have identified brain abnormalities involved in ADHD. The hypofunction of brain regions including the cingulo-frontal-parietal cognitive attention network have been consistently observed across studies. Meta-analysis has also shown a ventral-striatal hyporesponsiveness in ADHD. These are major components of neural systems related to ADHD, including attention and self-control networks, motor systems, and reward/feedback-based processing systems (Plichta and Scheres 2014). The ADHD neuroimaging research related to these network dysfunction are also associated with the core symptoms of inattention, impulsivity, and hyperactivity (Plichta and Scheres 2014; Castellanos and Proal 2012). These pieces of evidence suggest the biomarkers of diagnosis and treatment in ADHD prevention and intervention. However, these network abnormalities are not the only factors responsible for ADHD; instead, they are only part of the pathophysiology of ADHD. To fully characterize the disorder, based on recent advances in systems neuroscience-based approaches to brain dysfunction we should also consider the large-scale neural systems involved in ADHD in addition to the dysfunction of prefrontal-striatal circuitry (Tang and Tang 2015).

Treatment of ADHD. A national survey in the U.S. found parent-reported ADHD in 9.5% of school-age children; however, in European countries such as France, the percentage of children diagnosed with ADHD is much lower. Why? There are many possible reasons, including the differences in diagnosis and treatment as well as cultures. We here only discuss one of the major factors. In the U.S., we consider ADHD as a biological disorder and stimulants such as Ritalin are preferred treatment to combat these biological causes and symptoms. In contrast, French psychiatrists think that ADHD has psycho-social and situational causes and mainly look for the underlying issues in social context that contribute to the distress and symptoms. Therefore, they treat the underlying social context problem with psychotherapy or family counseling rather than focusing on using drugs to treat behavioral problems (Wedge 2015). In my opinion, ADHD involves both biological and psychosocial aspects; therefore, the holistic approach covering both psychosocial and biological aspects is an effective treatment for ADHD.

In Western culture, many students who have not been diagnosed with ADHD take medications prescribed for the disorder because they believe it will improve their attention, cognitive abilities, and academic performance. However, there are health risks and side effects associated with taking these medications. For example, these stimulant-based medications decrease appetite and cause difficulty in sleeping and other symptoms (Van der Oord et al. 2012).

In fact, except medications, methods of ADHD treatment include at least mindset change, maintaining a healthy diet and exercise regimen, mindfulness practice, and family and social support. Mindset often refers to the fixed mental attitudes and the way of thinking and opinions that predetermine our responses to and interpretations of situations, more like a habit. If a student holds a fixed mindset, she or he would believe that intelligence and talents are just fixed traits. This mindset limits the student's effort and performance in school as shown in previous studies. Similarly, we often hold the belief that ADHD is a disorder, and only rely on medications. However, we could change our mindset and take ADHD as a gift, not a curse; take it as an opportunity, rather than a disorder. In this case, we are more flexible to use our innate strength to work on these imbalance symptoms, this is in line with Eastern philosophy and wisdom: a balanced view and approach to harness the brain power and create a healthy life (Wedge 2015).

Mindfulness on ADHD. Except the pharmacological and behavioral treatments, mindfulness meditation has been shown to improve attention and self-control. Given that poor attention functioning is a core symptom of ADHD and self-control (executive functioning) deficits in ADHD are common, mindfulness meditation could strengthen these processes and help ADHD symptoms and treatments. We here propose the integrated translational model for mindfulness meditation as a prevention strategy on ADHD (Tang and Leve 2016). As shown in Chap. 2, mindfulness meditation includes at least three components that interact closely to constitute a process of enhanced self-regulation: enhanced *attention control*, improved *emotion regulation*, *and altered self-awareness*, all of which could potentially target the core symptoms of ADHD (Tang et al. 2015; Tang and Tang 2015).

Our and other studies showed the impact of mindfulness training on attention control, emotion regulation, and executive functioning through the improved activity and connectivity of the ACC/mPFC, striatum, and other brain areas (Tang et al. 2015), since mindfulness training can be subdivided into methods involving focused attention and open monitoring of present-moment experience. These two techniques involve different attention and self-control strategies and networks that may help ameliorate different ADHD symptoms. For example, "attention deficit" means brain hypoactivity that cannot support regular attention functioning (e.g., sustained attention), whereas "attention hyperactivity" indicates overactivity, such as impulsivity. Thus, focused attention and open monitoring mindfulness may each help the two extremes of attention problems in clinical practice. Therefore, treatment of ADHD symptoms using mindfulness should consider at least two strategies: one is to improve attention ability to ameliorate attention deficit and another is to reduce impulsivity and hyperactivity. These different methods target the two aspects of ADHD symptoms and help re-balance the innate attention capacity (Tang and Tang 2015).

Addictions

Studies of addictions have identified abnormalities in the frontal midline including the ACC, mPFC, striatum, and other areas, mainly involved in self-control networks. Using Stroop conflict tasks (index of executive function), one study by University of Oregon showed that, compared to a control group, adolescent long-term marijuana abusers showed a deficit in the ability to resolve conflict caused by an inefficient executive network involved in ACC. This result could be either the cause or the result of using the drug (Abdullaev et al. 2008). In either case, mindfulness meditation that could strengthen the activity and connectivity of the ACC may help the prevention and treatment of addictions (Xue et al. 2011, 2014; Tang and Leve 2016).

To verify this hypothesis, in one of our studies, we recruited smokers and nonsmokers who were interested in general stress reduction and randomly assigned them to either IBMT or an RT control. Before training, we compared smokers and nonsmokers and found that smokers had reduced activity in the self-control related networks including ACC and PFC during rest, indicating impaired self-control. This is in accord with previous findings showing that smokers often had lower PFC and ACC activity at rest than nonsmokers. We delivered 2 weeks of IBMT or RT (30 min per session and 5 h in total) to these participants. Among smokers, 2 weeks of IBMT produced 60% smoking reduction, 30% quitting, and significant decreases in craving. However, no significant reduction was found in the relaxation control. Resting-state brain imaging showed increased activity for the IBMT group in the ACC/PFC, brain areas related to self-control. These results suggest that brief mindfulness meditation improves self-control capacity and reduces smoking and craving (Tang et al. 2013).

More than five million deaths a year are attributable to tobacco smoking, but attempts to help people either quit or reduce their smoking often fail, perhaps in part because the intention to quit activates brain networks related to craving (Hartwell et al. 2011). We tested whether intention related to the reduction of smoking in a randomized studies in smokers and nonsmokers who underwent 5 h of IBMT versus RT. We found that conscious intention did not make a significant difference in smoking reduction and quitting. These results suggest that brief mindfulness meditation improves self-control capacity and reduces smoking even without a conscious intention to do so. But, how do we explain these findings?

Dual process models provide a role for both automatic (implicit) and controlled (explicit) processes that make complementary and interactive contributions to changing addictive behavior. "Automatic" refers to either attention or memory bias toward the substance cues related to the addiction, whereas "controlled" involves motivation and refers to a conscious intention that can be reported by the person. Since brief IBMT changes smoking behavior and habit even without a conscious intention to do so, one possibility is that smoking addiction is developed from an automatic process that happens immediately and without awareness. For instance, associative learning between smoking and various positive and negative emotional states occurs through repeated smoking behavior. When smoking related "cues" show up, they can induce different affective states and therefore trigger the urge to smoke. Later, this addictive loop becomes habitual and automatic, leading to cue-induced smoking behavior largely outside of our consciousness. Therefore, conscious intention does not make a significant contribution to smoking reduction: instead, brief IBMT changes smoking behavior that may mainly derive from implicit and unconscious control. These results suggest that mindfulness meditation can have an automatic effect even if the addicted individual is unaware that mindfulness training is being used as a strategy to reduce drug consumption (Tang et al. 2015c).

Many other forms of addiction, such as addictions to cocaine, marijuana, and alcohol, also involve deficits of self-control, and it is noteworthy to mention that studies have linked these addictions to operations of the ACC, mPFC, striatum, and other brain networks. These brain areas have been improved by short-term IBMT or other forms of mindfulness training, suggesting that mindfulness training could be an effective intervention for substance abuse (Tang et al. 2015d). Based on our and other findings, we propose self-control networks and addictions model (see Fig. 7.1) (Tang et al. 2015c).

Does mindfulness have effects on overeating behavior and obesity? Our brains are hardwired to respond and seek immediate rewards. Thus, it is not surprising that many people overeat, which can result in obesity, whereas others take drugs, which can result in addiction. Although food intake and body weight are under homeostatic regulation, when highly palatable food is available, the ability to resist the urge to eat hinges on

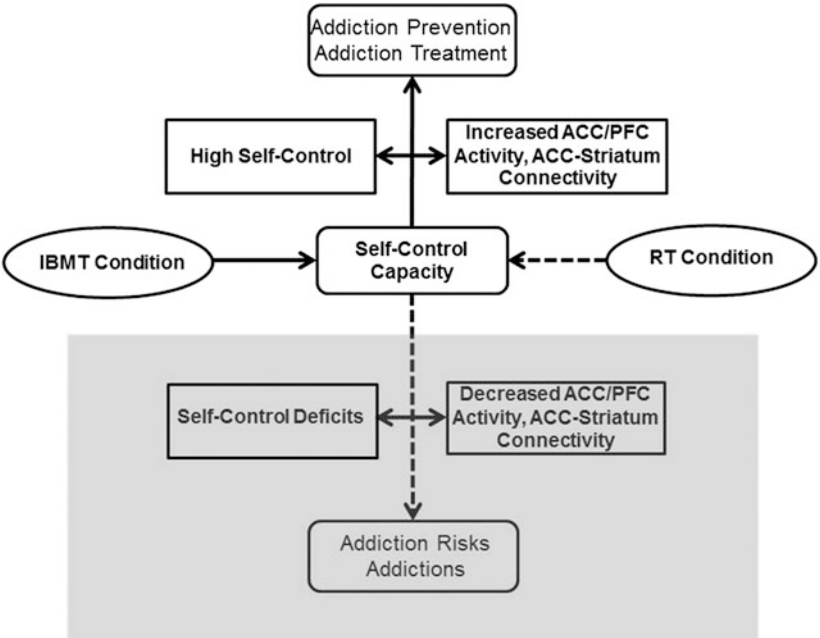

Fig. 7.1 Self-control networks and addictions. Self-control capacities improve following IBMT (but not RT) through increased ACC/PFC activity and ACC–striatum connectivity, and high self-control helps addiction prevention and treatment (e.g., smoking reduction or quitting). Self-control deficits are associated with decreased ACC/PFC activity and ACC–striatum connectivity, and addiction (gray area). Abbreviations: ACC, anterior cingulate cortex; IBMT; integrative body–mind training; PFC, prefrontal cortex; RT, relaxation training

self-control. The ability to resist the urge to eat requires the top-down control to inhibit the conditioned responses, which can lead to reward from eating the food and the desire to eat the food. Imaging studies show that obese subjects might have impairments in dopaminergic pathways that regulate neuronal systems associated with reward sensitivity, conditioning, and control. Since the neuropeptides that regulate energy balance (homeostatic processes) through the hypothalamus also modulate the activity of dopamine cells and their projections into regions involved in the rewarding processes underlying food intake, we speculate that this could be a mechanism by which overeating and the consequent resistance to homoeostatic signals that inhibits the function of circuits involved in reward sensitivity, conditioning, and self-control (Volkow et al. 2011; Volkow and Baler 2015).

Studies indicate that appetitive signals outside of conscious attention can influence ongoing or subsequent motivated behavior (McCabe et al. 2009). Exposure to food advertising during TV viewing may also contribute to obesity by triggering automatic snacking of available food, suggesting the power of food advertising to prime automatic eating behaviors (Harris et al. 2009). Mindfulness meditation has been shown to be helpful in promoting better eating behaviors and in the treatment of obesity, and assisting in weight regulation. These results support the efficacy of mindfulness for changing obesity-related eating behaviors, specifically in binge eating, emotional eating, and external eating. One reason may be an improvement in self-control following mindfulness training; another reason may be the dual process of unconscious and conscious regulation via mindfulness. However, more empirical works with randomized design and active control are still needed to determine the comparative effectiveness and long-term effects of mindfulness meditation (O'Reilly et al. 2014; Katterman et al. 2014; Mantzios and Wilson 2015).

Drug addiction and obesity appear to share several properties. Both can be defined as disorders in which the saliency of a specific type of reward (food or drug) becomes exaggerated relative to, and at the expense of, other rewards. Both drugs and food have powerful reinforcing effects, which are in part mediated by abrupt dopamine increases in the brain's reward center. The abrupt dopamine increases, in vulnerable individuals, can override the homeostatic control mechanisms of the brain. These parallels have generated interest in understanding the shared vulnerabilities between addiction and obesity. There is increasing evidence showing that the disruption of energy homeostasis can affect the reward circuitry and that overconsumption of rewarding food can lead to changes in the reward circuitry that result in compulsive food intake akin to the phenotype seen with addiction. Addiction research has produced new evidence that hints at significant commonalities between the neural substrates underlying the problems of addiction and at least some forms of obesity (Volkow et al. 2013b). Brain imaging suggests that both obese and drug-addicted individuals suffer from impairments in dopaminergic pathways that regulate neuronal systems associated not only with reward sensitivity and incentive motivation, but also with conditioning, self-control, stress reactivity, and interoceptive awareness, which mindfulness could strengthen and improve (Volkow et al. 2013a; Volkow and Baler 2015; Moeller and Goldstein 2014; Tang et al. 2015c).

In sum, studies have shown that, with the exception of addiction to tobacco, marijuana, alcohol and cocaine, various behavioral addictions such as obesity, gambling, and excessive use of the internet could also potentially be addressed with training of self-control networks in the brain. Brain-based intervention that strengthens self-control ability may be the most effective way to help addicts kick the habit. Combining improvements in self-control with appropriate motivation may be a particularly effective approach for treating addiction (see Chap. 5).

Balanced and Successful Aging

Given the rapidly aging populations in the world, it is crucial to understand how to promote and preserve important social, cognitive, and emotional functions so that older adults can have independent, balanced, and healthy lives, sometimes referred to as successful aging. But we prefer to use balanced and successful aging because balance in life is the sign of health and success. When people age, cognitive capacity and brain function decrease. Cognitive decline is commonly observed in advanced aging even in the absence of disease. To understand cognitive aging in healthy population, we first discuss the default mode network (DMN) in the brain resting state, and then the structural changes that occur.

Aging in Resting Brain. The DMN is often active when a person is not focused on the outside world and the brain is at rest but wakeful, such as mind-wandering and daydreaming. But it is also active when people are thinking about themselves and others. DMN shows deactivation in goal-oriented or attention-demanding tasks and is also called as the task-negative network. DMN mainly includes anterior parts of medial prefrontal cortex (mPFC) and posterior cingulate cortex (PCC)/precuneus. Studies have shown the disruption of this network in advanced aging. For instance, a study with adults aged 18–93 indicates that aging is characterized by marked reductions in normal functional brain networks. Especially, anterior to posterior parts of DMN are most severely disrupted with age. Furthermore, correlation reductions are severe in older adults free from Alzheimer's disease (AD), suggesting that cognitive decline in normal aging mainly arises from functional disruption in DMN (Andrews-Hanna et al. 2007).

Mindfulness on DMN. Given that DMN occupies over 90% of energy and resource in the brain while doing nothing in particular, it will significantly improve learning and cognitive performance if we could change DMN activity patterns and save brain resource. One of our RCT studies in young adults showed that compared to RT, five sessions of IBMT (30 min per session) significantly reduces anterior parts of DMN activity but increases brain activity at ACC and striatum (self-control and reward networks), suggesting the possibility and feasibility of changing DMN patterns through brief mindfulness training. Moreover, following brief IBMT, we have found significant improvements in diverse cognitive performance such as attention, working memory, creativity, problem solving, Stroop effects, and implicit learning. These results suggest that even brief mindfulness can save brain energy and resource and lead to better learning and cognitive performance (Tang et al. 2007, 2009, 2017).

The posterior parts of DMN/PCC is a highly connected and metabolically active brain region. Recent studies suggest it has an important cognitive role, and PCC amyloid deposition and reduced metabolism are seen early in AD. Neuroimaging studies have shown PCC abnormalities in a range of neurological and psychiatric disorders including AD, schizophrenia, autism, depression and ADHD, traumatic brain injury (TBI), as well as aging (Leech and Sharp 2014). This raises one possibility of whether mindfulness training could improve PCC activity or connectivity of anterior to posterior parts of DMN, thereby ameliorating cognitive decline, aging, behavioral problems, and mental disorders. We investigate this hypothesis in a longitudinal RCT study. This study is an interdisciplinary and collaborative effort between U.S. and Chinese research teams, and involves a 10-year study of a Chinese aging population trained by two different training regimes (mindfulness IBMT vs. physical exercise) previously shown to produce improvements in cognition and brain functioning in adults and elderly population. After comparisons between long-term physical exercise and mindfulness practice in an aging population, we found significant improvements in diverse cognitive functioning such as attention, learning, and creativity. Moreover, an improved connectivity between anterior and posterior parts of DMN was detected, suggesting that suggesting that longitudinal mindfulness practice may have reversible effects on cognitive decline in normal aging through ameliorating functional disruption in DMN (Tang 2009).

Aging in Structural Brain. The brain structure is constantly changing from birth throughout the lifetime. In healthy aging (free from dementia or AD), in addition to cognitive decline in executive functions, processing speed, and episodic memory, and changes in the brain resting state, structural brain changes can also happen. Studies show that the brain shrinks in volume and the ventricular system expands in healthy aging. In general, the greatest reduction is seen in the frontal and temporal cortex, as well as in the putamen of striatum, thalamus, and nucleus accumbens. A recent review article summarized MRI studies on age-related changes in the brain, and come to the same conclusion. Moreover, changes in cortical thickness and subcortical volume can be tracked, with an annual reduction between 0.5% and 1.0% in most brain areas (Fjell and Walhovd 2010). To test whether mindfulness training could induce greater gray matter, we conducted a RCT study in older adults (mean age: 55 years). Our findings indicate that in a 10-year follow up of seniors trained with IBMT, meditators showed better psychosocial behavior, cognitive capacities in attention, memory and learning ability, physiological indexes in cortisol and immune function sIgA, as well as brain function and structural changes in comparison to a matched exercise group. Most importantly, a key brain region, the striatum, which is involved in implicit process of skill learning and habit formation often shows decline with age, has been found to improve in structural plasticity after IBMT practice, indicating the potential reversibility effects of brain aging and learning deficits in aging population. We believe these studies will ultimately result in more effective brain health and self-regulation techniques for successful aging (Tang 2009).

It seems that shrinkage of neurons, reductions of synaptic spines, and lower numbers of synapses account for the reductions in gray matter. However, the length of myelinated axons is also greatly reduced during aging, up to almost 50%. This may shed light on the design of training or intervention methods for aging, which should focus on the myelination growth and maintenance in the brain. As we discussed above, 5–10 h of IBMT can significantly improve axon density and myelination associated with self-control networks, suggesting the possibility for prevention and intervention in aging population (Tang et al. 2013).

In sum, aging involves diverse cognitive decline, unhealthy physical and mental conditions, and reduced brain function and structure. Mindfulness meditation has shown positive effects on attention and self-control and has benefits on health and well-being over the lifespan, therefore it could be a preventive intervention to foster a cognitive reserve, and improve emotion regulation, as well as ameliorate aging related physical and mental conditions (Tang 2009; Tang et al. 2013).

Mood Disorders

Mood disorders refer to the psychological disorder characterized by the elevation or lowering of a person's mood, such as depression (or major depressive disorder) and bipolar disorder. Bipolar disorder is a combination of extreme elation (mania) and depression. Here we use depression as an example to explore the underlying brain mechanisms of depression following mindfulness meditation.

Major depressive disorder (MDD), also known simply as depression, is often characterized by pervasive and persistent low mood and lack of interest in normally pleasurable activities. Research has shown that depression is associated with self-control deficits. Convergent findings indicate that mindfulness meditation could ameliorate negative outcomes resulting from deficits in self-control and could consequently help patients suffering from diseases and behavioral abnormalities. Several clinical trials have explored the effects of mindfulness on depression and other mood disorders. However, only a few recent studies have investigated the brain changes following mindfulness intervention (Hofmann et al. 2010).

Several regions of the ACC are important in depression-related disorders. Depression is associated with dysfunction in various ACC regions. For example, increased resting glucose metabolism in the rostral part of ACC (rACC) seems as a promising predictor of treatment response in depression; however, the pregenual part of ACC (pgACC) has been shown to be hypoactivated in depression. Moreover, the ACC is also structurally affected in depression. For instance, lower gray-matter volumes of the rostral ACC extending into the dorsal ACC (dACC) are found in depression. These results may suggest that improved functional activity and structural plasticity of pgACC and dACC that support self-control ability are key areas in depression prevention and treatment (Walter et al. 2009; Pizzagalli 2011; van Tol et al. 2010).

Emerging data indicate that executive dysfunction or self-control deficit is an important feature of depression, and that recovery from depression precedes normalization of executive dysfunction. To test the relationship between executive function and brain mechanisms of depression following mindfulness intervention, we applied IBMT in a RCT study. Sixty-six college students were recruited and divided into two groups (33 with depression by clinical diagnosis and 33 healthy control, matched with age, education, and gender). They received one month of IBMT intervention (30 min per session, 10 h in total). We measured self-control ability using

Go/No-go and ANT tasks. At pre-test, the accuracy of Go/No-go task (patient vs. healthy group) showed significance, indicating the executive dysfunction or self-control deficit in depression group. However, at post-test, there is no significance between two groups, suggesting the improved executive dysfunction. Similar results were found using ANT task. At pre-test, conflict resolution of executive function (patient vs. healthy group) was significant, but at post-test, no significance was detected. Moreover, clinical symptoms of depression showed the significant improvements at post-test in patient group. These results suggest that depression recovery requires the normalization of executive dysfunction. If depression symptoms are improved at the behavioral level, how do brain responses support this positive outcome? We then conducted a neuroimaging study using SPECT to measure the cerebral blood flow (CBF) changes before and after 10 h of IBMT practice. We found that at pre-test, a global CBF decrease existed in the depression patient group compared to the healthy control. However, at post-test, a significant CBF increase in the ACC, PFC, and striatum was detected in the patient group, suggesting the recovery of brain function related to self-control. In combination with improvements of depression symptoms, our study indicated that short-term mindfulness practice can improve self-control and treat depression through strengthening self-control networks in the brain (Tang 2009).

In sum, previous results suggest that mindfulness is an intervention technique that is helpful for health, well-being, and some mental disorders, such as stress-related disorders, addictions, ADHD, and mood disorders. Although these studies are promising, future work needs to replicate these findings with more rigorous RCT designs with large sample sizes, and expand the emerging findings to optimally tailor interventions for clinical application (Tang et al. 2015).

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CHAPTER 8

Insight for Mindfulness Learning and Practice

Abstract There is much misunderstanding concerning learning and practicing mindfulness meditation. This chapter points out several common misunderstandings regarding mindfulness, and aims to provide readers with insight on how to learn and practice mindfulness efficiently. There are many ways of learning, but in general there are two types of learning strategies: implicit learning and explicit learning. Most people only believe and apply explicit learning to mindfulness meditation, but ignore implicit learning, which is also an effective method of skill acquisition. Based on many years of IBMT practice and teaching experience, this chapter proposes a novel and efficient way to learn and practice mindfulness both implicitly and explicitly.

Keywords Mindfulness learning · Mindfulness practice · Common misunderstanding · Insight · Implicit learning

The First Common Misunderstanding of Mindfulness Meditation

John read many articles on the positive effects of mindfulness and decided to learn it. He then bought several popular books on mindfulness and studied the concept and knowledge of mindfulness practice in great details. He also searched online and downloaded lots of applied materials including the mindfulness instruction manuals. Although he worked hard following the manuals, he still could not really enter in the "mindfulness state" he

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imagined or described in books and manuals. He felt that most of his mindfulness practices were dry and uncomfortable, although sometimes he had a feeling of relaxation. After a few months of practice, he gave up and thought mindfulness meditation was probably not a good fit for him. *This story reflects the first common misunderstanding about mindfulness learning and practice.*

Most people used to learn new things based on a concept and knowledge strategy stressing explicit learning. Therefore, they also learn mindfulness as a concept and knowledge (e.g., using a manual) rather than a direct experience. Can you imagine this picture: someone trying to learn how to swim in the water using a manual or book? In reality, this does not work well for learning a skill such as swimming. If you ask someone how to learn biking or swimming, you will be told: "just do it or practice it;" and you will then learn how to balance naturally. If you ask someone to describe in words how to float in water or balance on a bike, the person often could not tell you exactly how to float in water because this involves a different way of learning —implicit learning—through a direct experience and in an unconscious way, which always entails more than words can express (Tang 2009, 2017). Similar to what occurs in daily life, every night you lay down in bed to sleep, and your body naturally knows which position or posture is best for relaxation and rest. During this time, manual or language instruction does not help; you only need to follow the innate feeling—your body rhythm and wisdom—in order to fall asleep. Similarly, in mindfulness learning, the best approach is to first practice and experience, then understand and conceptualize. An experienced coach or trainer can help you and lead you into a deeper state directly through resonating with his/her direct experience, and we often use this strategy to guide novices in IBMT learning and practice. In the organizational behavior field, many studies have shown that a leader can influence and drive followers' emotions and behaviors, as well as affect their brain activity (Tang 2017).

Humans believe the purpose of reading is to accumulate knowledge, and this concept is not entirely false. However, the key is to not get attached to any words or concepts, because they are just stepping stones that are meant to be left behind as quickly as possible. In Zen spirit, this is called "fingers pointing at the moon." The words or instructions are just "fingers," and those whose gaze is fixed upon the pointer will never see beyond. Even if you catch sight of the moon, you still cannot see its beauty. Therefore, the moon is the truth you want to pursue. This metaphor can help you think about how to learn and practice mindfulness efficiently.

The Second Common Misunderstanding of Mindfulness Meditation

American culture is one representative of a "doing culture," in that the culture stresses that more effort and control—for example, being more "hard working"—is the only way to improve performance and achieve goals. However, this strategy does not fit mindfulness learning and practice well. In fact, some Eastern traditions favor effortless change (attention and action) in a completely natural and uncontrived way because this strategy more fits with the spontaneity of nature. Similarly, "trying not to try" has been proposed as another way to make changes by Western scholars recently, suggesting both effortful and effortless strategies are helpful (Bruya 2010; Slingerland 2014; Tang and Bruya 2017b).

The mindset that mindfulness needs strong mind control to clean up all your thoughts is not correct because by doing so, you take your own thoughts as your enemy in your conscious and unconscious mind and want to get rid of them. However, your thoughts are actually the exact reflection of your physical and mental states. If your physical and mental states do not change, your thought patterns remain the same. In fact, the right effort and appropriate control are the key to efficient mindfulness learning and practice. We often put considerable effort into a target such as breathing, thought process, and body feeling or sensation whenever we practice mindfulness. However, intensive and effortful practice makes our mind fatigue easily and even increases the stress hormone (cortisol) that can deteriorate and damage our body and brain/mind states. Some studies have shown that adverse events can occur with intensive mindfulness meditation during a retreat period. Therefore, only using mind control for mindfulness is not a natural method for our minds and for mindfulness practice. Trying hard to hold an object still is unnatural and difficult, because we restrict our attention so that it is narrow and static, but in reality the nature of mind is the opposite: natural, dynamic, relaxed, flowing, and spontaneous. *Trying hard to control the mind is the second common misunderstanding of mindfulness learning and practice.*

In nature, two seeds of the same tree in different environments can grow significantly differently, suggesting the impact of environment on growth. As mentioned earlier, research in organizational behavior has shown a leader's impact on followers' brains and behavior. This phenomena is also called 'contagion effect'. In sports, a million dollar coach can build a world-class practice program for athletes to succeed and achieve optimal performance. In the same vein, a qualified mindfulness coach or trainer has tremendous impact on a trainee's practice and mindfulness state. For example, during training sessions, an IBMT coach creates an environment and context for an effective learning and practice experience. The coach helps participants feel energy and sensation naturally beyond language and the logical mind. In contrast, following a detailed instruction in a manual sometimes does not work because this strategy involves processing our thinking more through language (Tang et al. 2007, 2012a, b, c). In addition, we also use metaphors as a means in IBMT teaching to further facilitate the mindfulness state. For instance, you hold a cup of ice water in your hands and immediately you can feel cold naturally, without any extra effort needed. Another example, an IBMT coach describes natural scenarios like catching the first glimpse of the sunrise and your mind registering its vibrancy, or getting the first feel of a breeze. In those moments, you are just there with full body and mind, right? The IBMT coach helps you be aware of that moment for a longer and longer time, so that the mind can reset and change. Moreover, an IBMT coach can help you achieve energy feeling or sensation directly that goes beyond language and thought processing. In other words, you are directly experiencing mindfulness practice by yourself rather than "thinking practice by yourself." Moreover, with continuous practice, you could even get a sense of "impermanence" through direct experience. In sum, even if you don't know how to plant an apple tree, you still can enjoy an apple.

As shown in Fig. 8.1, mind wandering and mental fatigue are two extremes of the untrained mind. Network training, such as computerized cognitive training and adaptive working memory tasks, often require continuous effort (effortful practice) to improve performance, whereas state training such as mindfulness meditation IBMT changes the body-mind state through effortless practice. Optimal balance (attention balance state) is hypothesized to trigger the most efficient performance–the deep meditative state (middle cylinder area) (Tang and Posner 2009; Tang and Bruya 2017b).

The Third Common Misunderstanding of Mindfulness Meditation

The third common misunderstanding of mindfulness learning and practice is how to deal with expectation. Jennifer is a professor and has long-term interests in Buddhist philosophy and psychology, mindfulness, and yoga. Over 30 years, she has accumulated more and more knowledge, but

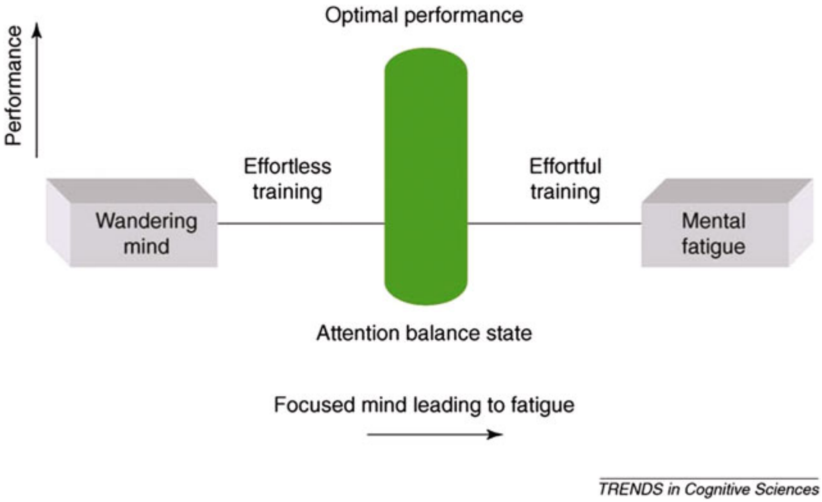

Fig. 8.1 Attention, effort, and performance

unfortunately she has never had a real and direct experience of mindfulness. When she learned of our series of IBMT studies on campus, and that most students without any knowledge and experience could enter in mindfulness meditation state following the instruction of a qualified IBMT coach, she contacted me and requested a trial session of IBMT. We invited her to attend one evening IBMT session at 8:00 pm; however, she was late and could only find a seat close to the main door of the conference room, which faced a road and was noisy. She did not know anything about IBMT and had no any prior knowledge and expectation on what IBMT session would be like; consequently, she just naturally followed the coach's guide to practice. This is exactly the right mindset for learning and practicing IBMT. During this session, she was in a very deep state of IBMT and for the first time she had a direct experience with pleasant feelings!

The next morning, she excitedly told me that her ego had been completely absent the previous night when she was in the IBMT session. She did not realize time passing during her practice—which is amazing and wonderful! This novel and deep experience was so attractive to her that she requested a second session of IBMT. When I noticed her strong demand and expectation of a certain IBMT feeling, I told her that the expectation of repeating certain feelings or experiences is actually the opposite of the mindfulness state, which is open, flexible, and non-judgmental. Although the expected mindset could disturb her practice quality, clearly she did not believe me. She arrived very early at 7:30 pm, before our session started, and told me that in order to repeat the same feelings and experience, she did nothing in particular in the whole afternoon and just waited for the night's session to begin. As I predicted, she did not get into the same deep IBMT state as she had the previous night because she wanted to control her feelings and experience so that they were exactly the same as before. In the end, she was very disappointed and upset. Jennifer's story actually provides an important insight during mindfulness learning and practice: experience first and conceptualize second.

In our series of IBMT studies, college students participate mainly for payment rather than for a certain expectation of meditation experience and feeling. Therefore, they are often open and flexible to any feelings and experience they may have, and there is no need to deal with expectations like those Jennifer had. This is also related to another key principle of mindfulness practice: trust the process. There are many things in the world that we don't know, but we believe we know, so we often follow our belief and preference rather than direct experience to guide our thinking, decision-making, and action. Therefore, our "filter" only allows us to see a part of the world and reality we want to see. In IBMT class, we invite you to follow the path of learning through doing and being. Put simply, first experience, and then conceptualization. We often suggest our participants not only focus on a goal they want to achieve through mindfulness, but instead, understand that "*the path is the goal*" (Tang 2009).

The Fourth Common Misunderstanding of Mindfulness Meditation

The last common misunderstanding I propose here is the separation of body and mind in learning and practicing mindfulness. As we discussed in Chap. 3, body-mind interaction is very important in mindfulness practice, especially in IBMT learning and practice. We often believe mental processes are more involved in mindfulness, and thus pay more attention to mind control. But in practice, mindfulness includes both physical and mental training. Body and brain/mind cannot be separated and are two important components to help achieve the mindfulness state. Based on previous research, I have proposed that mindfulness states can be achieved in two ways: through mental processes (e.g., mindfulness) and through bodily processes (e.g., bodifulness). As I described in Chap. 3, the bodifulness refers to the gentle and holistic adjustment and exercise of body posture through balance and harmony techniques (Tang and Tang 2015). For instance, in Eastern traditions, practices like IBMT, TCM-based methods (e.g., Tai Chi, Qigong), and yoga, apply body-mind balance and interaction techniques to facilitate body-mind states and positive outcomes. It should be noted that bodifulness is different from aerobic (physical) exercise based on our and other studies, as it mainly activates the parasympathetic part of ANS function, which leads to a calm and relaxed state (see our body-mind interaction results in Chap. 3) (Tang et al. 2009). Although mindfulness often involves an explicit process (e.g., counting your breath) through the CNS (brain/mind), bodifulness mainly involves implicit process (e.g., visceral or interoceptive awareness) regulated by the ANS. People often believe and apply explicit learning and practice to mindfulness meditation but ignore the implicit learning, which is actually an effective way to acquire skills such as mindfulness (Tang and Bruya, 2017b; Tang et al. 2017c). Based on many years of IBMT practice and teaching experiences, We have found that an efficient way of mindfulness learning and practice is to integrate body (ANS) and mind (CNS) both implicitly and explicitly.

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CHAPTER 9

Rethinking Future Directions of the Mindfulness Field

Abstract This chapter discusses future directions of the field of mindfulness, such as the from state to trait mindfulness, large-scale brain network dynamics in mindfulness, different stages of mindfulness and different states of practice, individual differences, the effects of combining mindfulness with other training regimens, and how to translate mindfulness into clinical practice.

Keywords Large-scale brain network · Individual differences · Physical exercise

Clarifying "Mindfulness"

In Chap. 1, I have clarified that, mindfulness is a mental state and direct experience rather than a concept. Therefore, the name of a mindfulness meditation or intervention with or without the term "mindfulness" should not define the nature of the program. Instead, the exact components and instructions of mindfulness practice are the key to define the program. Mindfulness methods always include several components, and there is no pure "mindfulness" with only one component of mindfulness. This chapter will discuss several aspects related to future directions of mindfulness field. With open minded and equanimous attitude and action, we believe scientific exploration and direct experience can help human beings achieve happiness, peace, compassion, wisdom, and self-growth.

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Large-Scale Brain Network Dynamics

Although it has long been assumed that brain functions are attributable to the isolated operations of single brain areas, more neuroimaging evidence now supports that idea that information processing results from the dynamic interactions of distributed brain areas operating in large-scale networks (Tang et al. 2015, 2017). The examination of interactions among large-scale brain networks has become a priority for cognitive and computational neuroscience research, as well as for the field of mindfulness research. The science of large-scale brain networks also offers a powerful paradigm for investigating learning performance and cognitive, affective, and social dysfunction in neuropsychiatric disorders. In my laboratory, we are using these systems approaches (resting and functional connectivity, small world topology, dynamic causal modeling, multi-voxel pattern analysis, Bayesian networks, machine learning, and neuroinformatics) to study multiple levels of brain processing such as effortless attention, implicit learning, working memory, learning habit formation and change, and cognitive and social development (Tang 2017). These new tools will allow us to understand neural coding (information representation patterns) and dynamics (how neural circuits manipulate, modify, and store information), and decode people's internal mental states related to performance and behavior. These tools could help us understand how large-scale brain networks support different stages of mindfulness practice and how these networks interact to establish, maintain and switch among different mental states. This research may also point the way to new interventions for strengthening self-control in healthy individuals and restoring it where it is impaired, as in mental disorders in the whole brain level. In addition, it allows us to explore and develop new in vivo body-brain coupling imaging technologies on the nervous system using both animal and human models.

Different Mindfulness Techniques and Different Stages of Practice

Different types of mindfulness practice may involve or emphasize different components. Within any technique of training, the stage of practice may involve differences in behavior, physiology, and brain activity. Two styles of training most commonly studied are: (1) focused attention meditation, which entails the voluntary focusing of attention on a chosen object; and (2) open-monitoring meditation, which involves nonreactive, moment-to-moment monitoring of the content of experience. Previous studies showed that portions of the ACC, PFC, and parietal cortex are involved at some stage in both of these mindfulness techniques, but results are not always consistent. One reason for inconsistent findings is that most studies average measures from different stages of meditation (early, intermediate, and advanced) to determine mechanisms or effects, or compare them without identifying the stage involved. Therefore, future research should separate the process of mindfulness meditation into different stages and then analyze data and draw conclusions (Tang and Posner 2013).

In general, mindfulness meditation can be roughly divided into three different stages of practice—early, intermediate, and advanced—each of which involves a different amount of effort during the meditation practice. The early and intermediate stages involve more control with effort, which differs from an advanced stage that occurs with more effortless practice. The early stage appears to involve the use of attentional control and often involves the lateral PFC and parietal areas. In the intermediate stage, participants learn to exert appropriate effort to deal with distractions and the wandering mind. This process involves diverse brain networks depending on the strategies used. In the advanced stage, little or no effort is needed, and meditation is maintained by activity in the ventral ACC, left insula, and striatum, accompanied by high parasympathetic activity. In this stage, there is a reduction of activity in the lateral PFC and parietal cortex (Tang et al. 2015).

From State To Trait Mindfulness

In Chap. 4, we discussed the trait and state mindfulness and pointed out that recent research has shown that our beliefs and attitudes are learned and shaped by our own experience and expectation, and that these personality traits are not fixed and can be changed. However, it remains unknown when mindfulness state will develop and transfer to trait following training. One idea is to follow a long-term practice (e.g., 10,000 hours in total) to develop certain traits and we hope to change traits or characteristics, but in reality, it does not seem always true because many people still keep the previous behavior, characters and habits. Moreover, studies have also shown that a short-term mindfulness training could induce state and trait changes. If so, what are the key factors involved? We propose a hypothesis that changes of brain structure might be a precursor of trait changes that drive new behavior and habit.

Research has shown that brain function and especially brain structure correlates with and support certain traits of temperament and personality (Whittle et al. 2006, 2014). In the same vein, mental disorders significantly affect certain traits of personality (Tang et al. 2016a). In a series of RCT studies, using IBMT vs. relaxation control, we found few hours of IBMT changes brain activity and cognitive and emotional performance (Tang et al. 2007, 2009). In the studies of diffusion tensor imaging (Tang et al. 2010, 2012), 2–4 weeks of IBMT (not the relaxation training) showed significant brain structural changes in the ACC and associated areas. Most important, after a 2-week IBMT, correlation between total mood disturbance change (an index of emotion regulation) and AD decrease in the left posterior corona radiata was significant, indicating that the training-induced change in emotion was correlated with the ACC structural changes, the self-regulation network in the brain. Furthermore, we found some trends in the changes of temperament and personality following IBMT, suggesting the possibility of state and trait changes following short-term mindfulness (Tang 2017). Although our results showed that short-term IBMT induces brain structure changes and correlates with trait-related changes such as emotion regulation, this warrants further investigation in other domains of characteristics in temperament and personality (Tang and Tang 2015a; Tang et al. 2016b).

Personalized Mindfulness Training

Individual differences of self-control and learning ability exist, and people respond to training and learning experience differently. Previous research indicated that gene × environment × behavior interactions shape the brain networks and drive behavioral changes such as cognitive, emotional, and social domains (Posner et al. 2013). Clearly, people respond to mindfulness meditation differently. These differences may derive from temperament, personality, or genetic differences. Studies in other fields have suggested that genetic polymorphisms may interact with experience to influence the success of training. For example, carriers of dopamine receptor D4 gene (DRD4) 7-repeat allele are more sensitive to environmental change, and this type of meditators may benefit more from practice compared to participants without DRD4 7-repeat allele; thus, it might be helpful to examine these polymorphisms to determine their possible influence on the success of mindfulness practice. Moreover, individual differences in personality, lifestyle, life events, and trainer–trainee dynamics are likely to have substantial influence on training effects, although little is known about these influences (Tang 2017). Our studies have shown that mood and personality can be used to predict individual variation in the improvement of creative performance following mindfulness meditation. Capturing temperament and personality differences may serve to predict success in mindfulness training because different temperament and personality traits are reported to be associated with different EEG patterns and HRV in meditators (see Chap. 6).

Since some human networks, including attention, are also common to nonhuman animals, by examining these networks and behaviors in animals using diverse methods of molecular biology and optogenetics, it should be possible to understand the role of genes in shaping attention and self-control networks and social behaviors following mindfulness training. We had reported cognition and emotion results related to stress, memory, learning, and social behavior using animal models and will integrate these results to further explore how gene × environment × behavior interactions shape the brain networks associated with cognitive and social behavioral changes. This research direction will eventually help design brain-based personalized training that can optimize our cognitive, emotional, and social capacity, as well as improve health and well-being and prevent diseases. Ultimately, these efforts will lead to personalized training, therapies, and medicine.

Combining Mindfulness With Other Training Regimens

In Chap. 7, we discussed a longitudinal comparison study of the training effects and mechanisms using mindfulness IBMT and physical exercise (PE) which have shown the positive effects on increasing physical and mental health. We found both IBMT and PE improve cognitive functioning, immune function and quality of life, but IBMT involves greater connectivity in a circuit including ACC, striatum and the parasympathetic branch of the autonomic nervous system, whereas PE induces lower basal heart rate and greater chest respiratory amplitude, congruent with PE's effects on training mainly the cardiovascular system. Since the mechanisms of PE and IBMT are distinct but complementary, our findings suggest combining physical and mental training in order to achieve better health, performance and quality of life (Tang 2009).

Some people feel the difficulty of meditation practice because it requiring many hours of dedicated training. Therefore people try to meditate for its health benefits, but often quit after the initial training due to the steep learning curve. Given that meditation state in part involves transient hypofrontality and reduced DMN activity, this raises one possibility to use other devices to facilitate this brain changes. One option is to apply a non-invasive brain stimulation technique such as Transcranial Direct Current Stimulation (tDCS) or Transcranial Magnetic Stimulation (TMS) to adjust brain excitability and inhibition to help meditator enter the state. Future research should examine whether the combination of tDCS or TMS with meditation could achieve better outcomes. If so, what the best stimulation protocols would be, such as target brain areas, frequency, length and dose.

Clinical Application

Some clinical trials have explored the effects of mindfulness meditation on depression, generalized anxiety, addictions, ADHD and other disorders, and the results suggested the efficiency of mindfulness practice for these conditions (Hofmann et al. 2010; van Tol et al. 2010; Tang et al. 2015). However, only a few recent studies have investigated the brain changes underlying these beneficial effects of mindfulness in clinical populations (Tang et al. 2015). One of the reasons might be the theoretical challenge. In other words, there have been less effort to integrate the existing basic and clinical literature into a comprehensive theoretical framework from a psychological, neuroscientific and clinical perspective although the number of empirical publications in the field has been growing very fast in the last decade (Tang et al. 2015).

Self-regulation deficits are associated with diverse behavioral problems and mental disorders, such as increased risk of ADHD, anxiety, depression, schizophrenia and drug abuse. Convergent findings indicate that mindfulness meditation could ameliorate negative outcomes resulting from deficits in self-regulation and could consequently help patients suffering from diseases and behavioral abnormalities. Therefore we first propose an integrative framework of mindfulness meditation which includes at least three components that interact closely to constitute a process of enhanced self-regulation: enhanced attention control, emotion regulation, and self-awareness (Tang et al. 2015). Then we adapt this basic framework to an integrated translational framework (as an common framework for mental disorders) to illustrate the neurobiological and behavioral mechanisms whereby mindfulness meditation could affect self-regulation outcomes including diverse mental disorders with deficits of self-regulation (Tang et al. 2012; Tang and Leve 2016).

Although the clinical studies in the field are promising, to best translate mindfulness into clinical practice, future work needs to follow the basic and translational framework and replicate and expand the emerging findings to optimally tailor interventions and treatments for clinical application.

A Balanced View of Mindfulness

Research over the past two decades indicate that mindfulness meditation—practiced widely for the reduction of stress and promotion of health—exerts beneficial effects on cognitive performance, physical and mental health, well-being, and brain plasticity. However, everything has two sides. For instance, although participants report relaxation and experience calmness in mindfulness practice, some also report various unpleasant feelings and reactions such as discomfort, anxiety, or agitation. Mindfulness is just one form of training or intervention techniques, but it is NOT everything. It is an attitude and a new skill, but it is not the only way to achieve the goals of health and well-being. In this current world of information overload, we propose that combining mindfulness practice with other training methods such as physical exercise may be more effective for diverse populations. Moreover, some studies have also shown that practitioners in long-term residential retreats who try very hard to control mind and practice mindfulness intensively every day often have high levels of the stress hormone cortisol, which can harm brain functioning and health. Therefore, appropriate effort and an optimal dose of mindfulness training is crucial in practice. As we discussed in this book, a balanced state is most important in learning and practice mindfulness. With regard to different ages of populations such as children, adolescents, adults, and elders who practice mindfulness, it is important to develop or find a proper method or technique that can fit different groups. Regarding patient populations with PTSD, schizophrenia, and epilepsy, or individuals who are at risk for psychosis or seizures, some concerns have been raised that mindfulness practice might put these individuals at elevated risk for exacerbation of these symptoms, or trigger adverse events or experiences such as a trauma or depressive episodes. However, there are few empirical studies on this topic thus far, so additional research is warranted.

In sum, mindfulness practice aims to increase mental flexibility and decreases psychological rigidity, which gives practitioners more choice and freedom, rather than restricting or limiting human capacity. Mindfulness facilitates a more open, centered, and engaged approach to living, rather than attachment of excessive reliance on a problem-solving mode of mind that may be the root cause of mental disorders and suffering. The only limit in one's life is the limit in one's mind.

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