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.

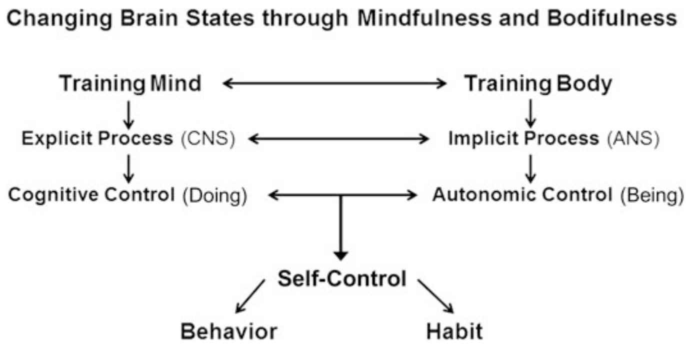

Fig. 3.1 An integrative model for changing brain states through mindfulness and bodifulness

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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