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Letter

Cognitive Processes Are Central in Compassion Meditation

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In responding to our recent paper in *TiCS* [1], Engen and Singer raise important issues related to the constructive family of meditation practice, arguing against the central role of reappraisal and perspective taking and proposing instead that motivational and affective states are the main mechanisms in compassion-based meditations, and more broadly in the constructive family [2]. Although we agree that motivation and affect have an important role in compassion meditation, we disagree with the broader conclusions they draw. We contend that classical and contemporary sources present a developmental model of compassion training that critically involves both reappraisal and perspective taking, and that scientific data support this view. Moreover, we propose that affect and motivation do not typically function as mechanisms in this family of meditation, but rather are best thought of as outcomes of the training process.

The Developmental Trajectory of Compassion Meditation

Traditional and contemporary sources outline a model of compassion training that typically begins with generating compassion for a specific individual, and then extending compassion until it becomes a natural response in all situations [3–5]. This developmental process typically takes place in three stages: (i) the generation of compassion; (ii) the extension of compassion; and (iii) the globalization and stabilization of compassion. Top-down cognitive processes have a critical role in each stage of practice. The first stage often involves the intentional generation of memories and thoughts that induce a feeling of compassion. One approach studied by the authors [6], for instance, recommends intentionally bringing to mind a loved one while silently repeating compassionate phrases as a way to stabilize attention [3]. Other forms of meditation involve taking on the perspective of a suffering individual or imagining them to be one's child [5]. In the second stage, perspective taking and reappraisal are used to extend compassion to strangers and adversaries by altering the way they are regarded, for example by focusing on their suffering and hardship rather than on their negative actions or qualities [4]. The final stage involves extending compassion to all beings and repeating the process until it becomes an automatic response. A typical method for extending compassion to all beings involves recalling one's own desire to be free of suffering, and then recognizing that all beings share this same desire [3]. This developmental process suggests that the affective and motivational state described by the authors is best thought of as the outcome of compassion training, with reappraisal and other cognitive processes functioning to arouse, extend, and stabilize this response.

Neuroscientific Research on the Cultivation of Compassion

The model outlined above suggests that cognitive, affective, and motivational processes are active at different stages of compassion training. Unfortunately, none of the studies cited by Engen and Singer provide a comprehensive account of the different stages of cultivating compassion. Moreover, none of the studies cited parsed the different stages of meditation with sufficient temporal precision and, thus, were not able to clearly distinguish between the processes engaged to arouse, extend, and stabilize the response versus the outcome or consequence of this initial engagement [6–9]. Therefore, the conditions included in these studies provide valuable information about the effects of compassion training, but do not fully represent the training process itself.

Contrary to the interpretation presented by Engen and Singer, we believe that extant data indicate the role of multiple brain networks in compassion meditation, including those associated with cognitive functions, even outside of formal periods of practice. A study from our laboratory, for instance, showed increased connectivity in response to emotionally provocative images between the dorsolateral prefrontal cortex (a region commonly linked to cognitive functions, such as reappraisal) and the nucleus accumbens, a central node in the reward network associated with positive affect, in those who underwent compassion training [9]. Connectivity between these regions has been linked to the successful use of cognitive reappraisal in the regulation of emotion [10]. Another study cited by Engen and Singer [8] showed heightened activation, also in response to emotionally provocative images, in brain regions such as the superior and inferior frontal gyri and the superior and inferior parietal lobules, which are typically activated in cognitive control processes, such as reappraisal [11], and similarly in the supplementary motor area and posterior cingulate cortex, regions involved in perspective taking [12].

When paired with data highlighted by Engen and Singer, these findings suggest that cognitive, affective, and motivational networks all have a role in the cultivation of compassion. This interpretation aligns with traditional contemplative theories related to the constructive family, which often use cognitive strategies to either up- or downregulate emotional responses. Future longitudinal studies will provide a more precise delineation of the processes that are engaged at specific phases of meditation training. At this early stage of scientific inquiry in this area, it is important to resist the temptation to equate specific forms of practice with particular discrete brain circuits and to remain open to the complexity of these practices and their corresponding neural correlates.

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Forum

Cognetics: Robotic Interfaces for the Conscious Mind

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Cognetics joins the cognitive neuroscience of bodily awareness with robotics to study, control, and enhance perception, cognition, and consciousness. We highlight robot-controlled bodily perception, conscious states, and social interactions and sketch how future cognetic interfaces will impact cognitive neuroscience and human enhancement.

Robotics

Since ancient times humans have entertained the idea of being served by automatons or intelligent machines. Robots (from the Czech word ‘robota’, servitude), especially industrial robots, now ‘serve’ humans by assisting them in a wide range of repetitive, high-precision tasks, and many complex operations, mostly in manufacturing. Autonomous robots have impacted domains such as industrial inspection, locomotion, aviation, education, entertainment, and home automation (domotics). Some of these technical advances have also been applied in medicine and neuroscience. Robots have allowed improvements in the design of interfaces to enhance human motor skills such as in robot-assisted surgical procedures (i.e., suturing an artery during medical interventions) with impact on surgical precision and patient care. They have also become major neuroscience tools, and have been used for probing the brain mechanisms of motor and sensorimotor processing [1]. However, despite these important achievements, we believe that robotic devices are not sufficiently employed to study or enhance human cognitive functions, such as attention, memory, thought, language, perception, or consciousness. We propose that this gap can be bridged by intensified bidirectional research between new robotic interface design and the cognitive neuroscience of body perception and awareness, launching what we propose to call ‘cognetics’ (Box 1). Based on recent studies highlighting the importance of multisensory and sensorimotor bodily signals for cognitive functions and consciousness, we describe how cognetic technology will interface the body with brain systems for cognition and consciousness.

Box 1. Robotics and Cognetics

Robotics is a branch of engineering that deals with the development of artificial devices able to sense and act upon the body and the environment. Since the employment of robots for improving repetitive manufacturing tasks, robotics has taken many directions for ‘serving’ human activities. One line of work has focused on the development of autonomous and/or mobile systems that are of great importance for diverse fields such as aviation, industrial inspection, and home automation. Cognitive robotics focuses on endowing robots with intelligent behavior through the development of computational architecture, thereby allowing artificial learning and decision-making. Another line of work has focused on interfacing robots with the human body with the aim of controlling and enhancing human motor skills. More recently, these interface-oriented developments in robotics have been enriched by the creation of haptic devices, aiming to artificially create a large range of tactile sensations by robotic stimulations on the user's skin. Cognetics and cognetic devices are haptic interfaces with the ability to render and combine artificial multisensory stimuli with movement and related motor signals. This optimized robotic integration of multiple sensory and motor signals makes cognetic interfaces the key technology to investigate and enhance bodily perception, consciousness, and related cognitive functions.

Cognetics for Consciousness and Cognition

Extending the use of engineering-based methods in the neuroscience of sensorimotor control of hand movements, cognetics was pioneered by investigating self-other discrimination and conscious sensations associated with action (i.e., agency). Developments in MRI-compatible robotics also made it possible to measure brain activity while robotic devices influenced well-defined bodily experiences with precision [2]. Even complex conscious states and hallucinations that are only found during altered states of consciousness have been induced by such sensorimotor robotic systems [3]. This automatized control of bodily signals is now tested in dyadic sensorimotor robotic connections mediating interactions between two individuals [4]; this will likely propel forward investigations of multiuser social interactions, perception, and decision-making processes (i.e., social biases, trust in others) [5].

Key cognetic technologies include interfaces and wearable technology, which rely